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ABSTRACT

Selections of papers from the 19th annual conference of the Australian Science Education Research Association are presented in this volume. A diversity of themes are addressed and include new topic areas as well as concerns that have been cited in previous issues. These papers focus on issues including: (1) students' misconceptions; (2) classroom practices and processes; (3) professional development; (4) scientific literacy; and (5) the history of scientific ideas. Research notes, the addresses of authors, and guidelines for the submission of papers are also provided. (CW)

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RESEARCH IN SCIENCE EDUCATION

Volume 18

Selections of refereed papers from the Nineteenth Annual Conference of the Australian Science Education Research Association held in Sydney, New South Wales, July 1988.

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EDITORIAL COMMENTS

In the last issue of Research in Science Education readers of the journal were invited to comment about the mix of descriptive and investigatory papers included in Volume 17. As no comments were received the editorial committee assumed either that no one reads the preface to an issue, or that readers do not object to the variety in the papers. If the latter is the case then readers will be even more pleased this year to see the greater diversity in the matters addressed. Certainly research on students' misconceptions still predominates, but research in science education appears to be in a healthy state as there are people directing our attention to other important areas including classroom processes, professional development, scientific literacy in adults and the history of scientific ideas.

Richard P. Tisher

Editor

Research In Science Education, 1988, 18, 1-8.

DEVELOPING PROFESSIONAL SKILLS IN CHEMISTRY

- AN INITIAL STUDY

Christopher Kirk

INTRODUCTION

In 1978 the Chemistry Department at the University or Waikato introduced an industry-orientated degree, the Bachelor of Science (Technology). This 4-year degree includes the components of a normal Bachelor of Science degree integrated with additional vocationally-related courses and twelve months of industrial experience. It was set up "to meet the needs of students who have an interest in an industry/applied career in chemistry and to meet the demands of employers for graduates with some working experience in such courses" (Anon, 1980).

To extend our awareness of the employer's perspective, the pilot study reported here was undertaken to investigate the needs and expectations of industrial employers. The main aim was to identify the professional skills and attributes employers look for in new chemistry graduates. It was intended that this information could then be used to design a wider investigation of the skills required by professional chemists and of the role of university degree courses in developing these.

This report contains the main outcomes of this pilot study.

PROCEDURE

A "naturalistic" approach involving detailed interviews with a limited number of subjects (Cohen and Marion, 1980) was adopted for this project. Selected industrial plants and laboratories were visited and audiotaped discussions were held with appropriate personnel (Chief Chemists, Technical Managers, etc.) on a range of issues relating to tertiary chemistry courses and the needs of the workplace. Background material was supplied well in advance of these interviews. Emphasis was placed on how well prepared (first degree) graduates were to meet "chemistry in the real world" and, in particular, on identifying skills or knowledge areas in which graduates seemed to be inadequately prepared. Interviews occupied approximately 40 minutes.

The industries chosen for these discussions represented a cross-section of the New Zealand chemistry scene. All employed chemistry graduates. Thirteen sites were visited and 21 in-depth interviews were carried out. It should be noted that the term "industry" is used here to denote any area outside of the educational sector from Government research laboratories to privately owned companies.

ANALYSIS OF DATA

Analysis and presentation of the information obtained was carried out by transcribing the audiotapes, analysing for the main issues raised, then grouping these issues into general areas.

The professional qualities thus identified by the employers as being desirable for graduates to possess upon entering the chemistry-based workplace can be presented in 5 broad categories. A summary of the major issues within each category is given below with a brief commentary. It has to be recognised that in a study of this kind, the views expressed result from a wide diversity of backgrounds and experiences and inevitably reflect a range often conflicting opinions. Since the context in which individuals saw issues adds an important reality and richness to the views expressed, extensive use has been made elsewhere (Kirk, 1987) of direct quotations (in italics) to present viewpoints in their true perspective. Only a few examples are included here.

1. Issues Associated with Analytical Chemistry and Quality of Results

Summary

The major issues identified were the need for improved:

- analytical skills
- understanding of analytical methodology
- data handling and interpretative skills
- awareness of the implication of quality assurance for analytical methods/results.

Comment

Disappointment at the level of manipulative analytical skills, from the very basic (use of a pipette was a favourite) through to maximising instrument performance, brought considerable comment. It appears that, after 3 years of tertiary chemistry, many graduates are not able to perform basic laboratory techniques adequately.

> "....often have very poor practical skills like how to use a pipette. We really have to take them though a basic laboratory skills programme for the first few weeks."

The point was made that if graduates are to be placed in charge of groups of technicians it is essential that they know and understand the correct technique and why it is important. They need to be able to check, trace and identify problems associated with analytical methodology.

It was felt that many graduates lack a real "feel" for the principles and underlying difficulties of performing accurate analyses and for the general applications and limitations of analytical methods and instrumentation.

> "Time and again we find new graduates joining us who have a general familiarity with techniques, with what they will do, but they don't have a very good familiarity with the way that you really have to tread very cautiously and check perhaps nearly every stage when doing an analysis that might have gone wrong."

It was also suggested that graduates are generally unaware of the role and importance of standards in industrial analyses and that they are not familiar enough with the standard reference method texts of analytical chemistry. Pleas were made for full recognition of the value of analytical chemistry as a specialty area in its own right, rather than treating it as a service course. The importance of being able to handle analytical data and to interpret it was stressed repeatedly. The need for improved familiarity with microprocessor/computer systems (not programming) and the application of basic statistics to obtain useful interpretations from cumulative data were emphasised.

2. Issues Associated with Communication

Summary

The major issues identified were the importance of:

- report-writing skills
- general communication (and people) skills
- group-working skills

Comment

Report-writing skills received a great deal of negative comment. From this it would appear that for any course aiming to "meet the demands of employers", careful consideration should be given to the educational opportunities to develop this skill (cf. positive comments made about this aspect of Chemical Engineering education).

> "Many chemistry graduates are not good at writing reports. Their English is often poor and they appear to have had little experience or practice in report-writing. Our chemical engineers on the other hand are better trained in this area when they arrive."

It was claimed that graduates are generally unaware of how to write reports that are reader-orientated, contain clear interpretations of data and results, are logical and well presented, and include a concise summary.

Perhaps most disturbing were the assertions that current chemistry degree programmes are actually a disadvantage in developing report-writing skills.

> "With report-writing, graduates start well behind people who haven't been to university (that is, it's an actual disadvantage). It's because they are taught to be too self-centred and their orientation is all wrong. Their focus is on what I am writing, what I have done, what I have found interesting, what my theories are, whereas in fact the report should be addressed to what the reader needs to know, what are the most important things for him, what is relevant to him - and these two approaches are not the same usually. So (graduates) have a lot of trouble. It's obvious why they've been taught to focus on themselves - they are being examined on what they have done and what they have learnt, but I don't give a damn about that when someone's working for me. What I want to know is: what are the answers, what action do we need to take, and also I want to know in words I can understand. So for that reason I think they do start at a disadvantage, and this is a reasonably widespread opinion too."

The importance of communication in general (and oral in particular) in the workplace was repeatedly stressed. It was emphasised that there is little point in knowing or doing "chemistry things" unless the information can be passed on effectively.

3. Issues Associated with Problem-Solving

Summary

The major issues identified were the need for:

- an ability to look up information, to use data bases, to carry out computer searches
- an introduction to various strategies for problem-solving
- an awareness of time and cost constraints, approximate vs complete solutions
- some practice at solving "real" problems, evaluating choices and making decisions

Comment

Solving problems is a major function for many chemists in industry. The type of problem-solving referred to here is the process of finding a solution (or a range of solutions) to the real problem that a professional chemist is often confronted with. Usually the solving of such problems calls for the development of a strategy rather than just the application of known procedures. It appears that current chemistry courses, for all their worked examples and problem sheets, do little to enhance the development of broader problem-solving skills. These are condidered particularly valuable and relevant to the education of applied chemistry students.

Several suggestions were made on how to promote these broader problem-solving skills. For example, being familiar with a range of problem-solving strategies, adopting a broad overview as well as the specialist detailed approach, appreciating the realities of time and cost pressures and the appropriateness sometimes of quick and approximate solutions (cf. the complete answer) were mentioned. In particular, the opportunity to have some experience in dealing with the "industrial" type of problem (rather than "pure" chemistry problems only) was commented on.

Another important skill related to problem-solving is the ability to use efficiently relevant library sources, data bases, etc. to gather information pertinent to an investigation. While some graduates were reasonable proficient, the need for opportunities to develop this ability was emphasised.

4. Issues Associated with Management

Summary

The major issues identified were the need for some introduction to :

- project management skills
- the role and importance of industrial economics
- laboratory managment
- general people skills

Comment

The discussions suggested that, for both graduate and employer, an introduction to selected management and related skills would be desirable. Very little, if any, exposure to these areas appears to be available in a traditional chemistry degree. The topic areas suggested as being valuable for any chemistry graduate to have had an introduction to included:

(a) Project Management: an introduction to evaluating projects before undertaking them and during their progress.

(b) Economics/Business Management: an introduction to industrial economics, balance sheets, cash flows, etc.

(c) Laboratory Management: an introduction to selected activities associated with routine laboratory management, such as ordering equipment and chemicals, safety aspects, organising and planning, people interaction.

(d) Interpersonnel Skills: an introduction to the general area of interacting with people (given high priority by industry).

5. Issues Associated with Learning at University and the Transition to Industry

Summary

The major issues identified were:

- traditional values of university education
- adequate levels of knowledge of general academic chemistry
- need for awareness of differences between university and industry chemistry
- miscellaneous topics for inclusion in applied study programmes.

Comment

It is worth noting that the qualities traditionally associated with a university education - the ability to learn, to think logically, etc. - were favourably commented on and are still considered important.

Generally, employers found little fault with the level of academic chemistry knowledge possessed by graduates (cf. practical skills above). Employers did not expect graduates to have detailed knowledge about their own specific industry or products and generally found new graduates well capable of learning the specific new chemistry 'knowledge' relevant to that employment.

However, it was suggested that some awareness of the differences between the role of a chemist in a university setting and in industry would assist in the transition from student to professional chemist.

A number of additional topic areas were considered important enough to be recommended for inclusion into courses preparing graduates for industrial careers (Kirk, 1987).

DISCUSSION

The main purpose of this report is to present the data gathered in this investigation in some ordered way. It is not considered an appropriate forum for a full discussion of the many and complex issues associated with the "University-Industry interface" that this study impinges on.

From the limited data gathered, there appears to be a considerable mismatch between those professional qualities desired in graduates by industrial employers and those generally found at present. It is clear that in addition to a knowledge of the facts, theories and techniques of modern chemistry, a professional chemist is expected to have numerous other qualities.

From both the employer's and the graduate's point of view, the ability to achieve results is probably the most important attribute a newly - graduated chemist can bring to the workplace. The evidence indicates that to do this a wide spectrum of qualities is needed:

- those which relate to specific knowledge and skills (e.g. devising a synthetic method, using an instrument, reading the literature)
- those which are more generalised (e.g. problem-solving, decision-making, ability to learn, communicating, planning, working in a team)
- those which relate to attitudes (e.g. confidence, commitment, enthusiasm).

Questions immediately arise as to the extent these qualities should be developed within the formal education system and how much they should be learned on the site of employment. It appears from the views expressed in this study that curently there is a very considerable learning curve for graduates in their first jobs. What would help shorten this? What is important for the longer-term professional development of the graduate?

In searching for general reasons for the perceived mismatch (from the employer's viewpoint) between desired and achieved qualities, some general comments may be made. For instance, the notable lack of criticism of 'knowledge' in the traditional content areas of the academic subject 'Chemistry' was significant. University Prescriptions indicate that in most chemistry courses, the majority of effort and achievement (by staff and students) is weighted heavily towards 'knowledge'. Knowledge is important - skills have little value unless they are combined with chemical knowledge. It may be considered by some that knowledge is so important that there is insufficient time to develop other professional qualities (to any significant extent). But does the teaching of 'knowledge' need to be at the expense of developing other professional skills and attitudes, or are there methods of teaching that can encourage the learning of 'skills' and 'attitudes' at the same time as 'knowledge' (and vice versa)?

Another notable (and unexpected) feature of the opinions found in this investigation is that they seem to question the common assertion that the study of chemistry develops problem-solving and decision-making skills. It is suggested that current chemistry courses may do little to help with problems where the solution calls for the development of a strategy rather than just the application of known procedures. Could the use of alternative teaching approaches or alternative types of problems enhance the development of these wider problem-solving skills - and perhaps involve aspects of decision-making and innovative thinking as well?

From such considerations a number of general questions arise - for instance:

1. Where does responsibility lie for developing specific professional qualities?
2. Should these professional qualities be addressed only by industrial/applied chemistry courses?

3. Can skills and attitudes only be developed at the expense of chemical knowledge?
4. Are there alternative teaching and learning strategies by which more emphasis could be given to developing skills and attitudes in traditional chemistry courses?

CONCLUSIONS

The limited data gathered in this pilot study suggests there may be a considerable mismatch between those professional qualities desired by industrial employers and those they generally find in new chemistry graduates. The issues raised seem sufficiently important to warrant a wider investigation. It is intended to use the data found in this initial study to design a more detailed survey in a second phase of this project.

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Research In Science Education, 1988, 18, 9-21.

HIGH SCHOOL STUDENTS' QUESTIONS IN BIOLOGY:

COGNITIVE LEVELS AND CONTENT THEMES

Reuven Lazarowitz & Orna Meir

Biological science instruction frequently utilises the strategy of representing subject matter in pictorial form. The imposed strategy makes use of pictures from external sources, while in the induced strategy, students represent the subject matter by their own drawings (or sketches) (Alesandrini & Rigney, 1981).

The role of pictures and their effects in science education and on students' academic achievement were described by Dwyer (1972), Holliday (1973; 1975) and by Szabo et. al. (1981). According to Brody (1983) pictures can be examined for the functions they can serve. Knowlton (1966) emphasised that pictures which represent objects or events can provide an opportunity for logical relationships, making analogies and stimulating observers to think at different cognitive levels. Duchastel (1978) concluded that pictures can be used to attract students' attention toward a learning task, to facilitate the explanation of specific content or to help students remember what they had been taught. Other functions for which pictures can be used suggested by Levie and Lentz (1982) are gaining and directing students' attention, affecting emotions and attitudes, and improving comprehension and retention.

Brody (1983) mentioned that understanding the instructional function of pictures is important in clarifying issues such as how information provided by pictures is processed and how pictures may affect cognition and perception.

Holliday (1973) claimed that "certain kinds of pictures facilitate the learning of certain types of objectives for certain students with certain kinds of characteristics". Holliday (1973) noted Dwyer's (1972) conclusions that the use of pictures in instructional procedures had a variable effect on student performance.

Explaining "what's in a picture?", Holliday (1975) asked whether pictures can help students to understand better a science lesson. Further, he suggested that it is important to ask students how they used a picture when they studied a specific concept in science. Students' responses might provide grounds for developing a strategy of instruction to help students to identify structure and function relationships, one of the most emphasized principles in teaching biology in high schools (Holliday, 1973). Although Koran and Koran (1980) found that the use of pictures of the heart did not help biology students to identify the relationships of structure and function, they did find that pictures, when used in advance of a text, "may provide a scheme for organizing incoming textual material".

Knowlton (1966) pointed out that pictures represent objects and that therefore they may induce different stimulations in observers. Obtaining information about how each learner perceives the characterstics of an object is important if we are interested in understanding how learners perceive and interpret objects. This knowledge may facilitate the teaching and learning process in the classroom.

In this study pictures representing six levels of biological organization (LBO) (cellular, tissue, organ, organism, population, and community) were used to stimulate high school students to generate questions related to what they would like to learn about the biological subjects exposed in the pictures. Subsequently, these questions were analyzed for fluency, cognitive level, and biology content theme (concepts, principles, structure and function).

Levels of Biological Organization

Schwab (1966) identified seven levels of biological organization which represent biological subject matter structure from an evolutionary point of view. The seven LBOs comprise molecular, cellular, tissue and organ, organism, population, community, and biome. Most of the high school biology textbooks (including the one used in this study) follow this conceptual structure and include biological subjects in the above LBO sequence, starting with the reductionist levels (molecular, cellular) and ending with the holistic levels (population, community, biome). The problem of adapting the biological topics to the learning needs of students of different ages (the reductionist or the holistic levels) for instructional purposes was discussed by Hurd (1967) and Ausubel (1968).

The Cognitive Level of Questions

The fluency of questions as a measure for creativity is discussed by Torrance (1980). Blosser (1987) discussed the importance of questioning in science education. The cognitive level at which students function is one of the main areas investigated in education. In this study we used Bloom's (1956) cognitive taxonomy, and student questions were clustered in two categories: low and high cognitive level. According to Hurd (1961) it is important that students' cognitive level of development should be considered in order to adapt learning material and instructional strategies to students' modes of cognitive operations. In their study, Tamir and Kempa (1978) mentioned that while many studies investigated what students "can do from the cognitive point of view, very few studies investigated what they actually do in terms of cognitive operational level". They reported that most students in their study displayed a cognitive preference toward recall and principles rather than for applications and questioning. A strong relationship was reported between teaching strategies and students' cognitive preferences (Tamir & Kempa, 1978).

Thus the following research questions were asked in this study:

1. What are the cognitive levels of the questions asked by students in grades 9, 10 and 11?
2. Which biological content themes were present in the students questions?

The independent variables were: six levels of biological organization (LBO) exposed in the pictures (Schwab, 1966); student age (Grade 9, 10 or 11) and student gender. The dependent variables were: the fluency of student questions; the cognitive level of questions (Bloom 1956); and the biological content themes of the questions (Klinckman, 1970).

METHOD

Subjects

The sample consisted of 588 high school students from seven comprehensive high schools in Israel. Twenty eight classrooms were involved in the study including 10 ninth grade classrooms (n=187: boys=83; girls=104); 12 tenth grade classrooms (n=283; boys=79; girls=214); and 6 classrooms of 11th grade (n=103; boys=26; girls=82). In total there were 400 girls and 188 boys.

All schools in the study used the Biological Sciences Curriculum Studies (BSCS, 1975) An Inquiry into Life: Yellow Version as their main textbook. The book is organised so that students in the ninth grade study a section entitled Unity (molecular and cellular levels which are based on a reductionist approach); tenth graders study Diversity (tissue, organ, and organism levels); and eleventh graders study Continuity and Interaction (population, community, and biome based on a holistic approach). Students in grade 11 are exposed to the themes of development, continuity, reproduction and behaviour. While studying these topics, the students are re-exposed to the molecular and cellular levels with a greater emphasis on the biochemistry components of the physiological aspects of these themes. In all four sections, the relationship between structure and function are emphasized and the ultimate aim is for students to master the main concepts and principles presented in these LBO.

TABLE I
Content validity of the 30 pictures representing
6 levels of biological organization

Picture	Contents	Level of Biological Organization	Inter-judge Agreement in %
1	An egg and sperm cell before fertilization.	Cell	100
2	A mitochondrion and the endoplasmic reticulum.	Cell	93
3	An animal cell and a nucleus.	Cell	100
4	A bacterium cell.	Cell	100
5	A mitochondrion in muscle cells.	Cell	93
6	A vascular bundle of monocot stem.	Tissue	93
7	Blood cells (human body).	Tissue	90
8	Spinal cord - transverse section (human body).	Tissue	86
9	Muscle cells (human body).	Tissue	80
10	Scattered bundles - the arrangement of a vascular tissue in a dycot plant.	Tissue	80
11	Heart - vertical section (human body).	Organ	86
12	Soybean roots bearing modules of Rhizobium.	Organ	86
13	Kidney - vertical section (human body).	Organ	100
14	Dendelion taraxacum officinal - seed dispersal.	Organ	80
15	Digestive system - stomach and other organs (human body).	Organ	93
16	Mosquito (Aedes Albopictus).	Organisms	100
17	Earthworm (Lumbricus Terrestris).	Organisms	100
18	Hare.	Organisms	93
19	Iguana.	Organisms	100
20	Frog (Rana Esculenta).	Organisms	93
21	Desert snakes after hatching.	Population	93
22	Population of plants (Pancratium Maritimum).	Population	80
23	Population of Haematopus Ostralegus (chara druformers).	Population	100
24	Population of palm trees (Hyphaene Thebaica).	Population	80
25	A deer and a herd of roes.	Population	93
26	Fish, coral and sea lily.	Community	86
27	Carmel flora - northern and southern slopes.	Community	100
28	A heron and a crocodile on a river bank.	Community	80
29	Flora in a creek.	Community	86
30	An hippopotamus and different birds.	Community	93

TABLE II
Questions' Fluency by LBO, Grades and Gender: Means and F-Values

Grades	N	Cell	Tissue	Organ	Organism	Population	Community	
				Low Cognitive Level in %				Total
		x	x	x	x	x	x	x
9th	187	10.45	11.60	14.00	19.80	17.41	19.32	15.90
10th	293	18.84	17.20	18.51	24.89	22.89	19.18	20.40
11th	108	13.79	14.30	15.31	18.21	15.10	19.76	16.22
F-Values		3.44**	3.86**	2.82**	2.88**	5.92*	NS	12.19*
				High Cognitive Level in %				Total
9th		0.45	1.10	0.75	0.89	0.63	1.71	0.76
10th		2.04	2.02	1.18	0.96	0.93	1.30	1.37
11th		1.79	1.64	0.63	1.25	0.70	1.62	1.32
F-Values		4.63**	NS	NS	NS	NS	2.62***	6.67*
Gender				Low Cognitive Level in %				Total
Boys	188	15.82	12.84	12.32	19.05	18.77	18.61	16.51
Girls	400	15.82	15.55	18.49	23.49	20.48	19.63	19.00
F-Values		NS	NS	5.68*	2.42***	NS	NS	4.83**
				High Cognitive Level in %				Total
Boys		1.21	1.56	0.77	0.76	0.86	1.25	1.03
Girls		1.62	1.68	1.03	1.19	0.75	1.18	1.23
F-Values		NS	NS	NS	NS	NS	NS	NS

MANOVA: Interactions Effects and F-Values

	Low Cognitive Level	High Cognitive Level	Cognitive Level
Grade	12.74*	7.11*	15.98*
Gender	6.41*	NS	NS
LBO	7.84*	3.35**	4.25**
Grade x Gender	NS	NS	NS
Grade x LBO's	NS	NS	2.12**
Gender x LBO's	NS	NS	NS
Gender x Grade x LBO's	NS	NS	NS

* P<.01
** P<.05
*** P<.10
NS = Non significant

Instrument

The instrument used to stimulate students to ask questions consisted of 30 picture-photographs which represented the six levels of biological organization.

The 30 pictures were selected from a pool of 50 by 12 student-teachers (ST) in biology and three high school biology teachers. This panel of teachers and ST reached a level of agreement about the relation of each picture to a specific LBO in excess of 80%. This interjudgmental agreement provided a measure of content-validity of the instrument. A short description of each picture, the LBO to which the picture belongs, and the inter-judgmental agreement values (expressed as percentages) are displayed in Table I.

In order to determine the reliability of the procedures for analysing students' questions the following analyses were performed. Out of the total of 11,435 questions asked by the students in relation to the six LBO a sample of 656 questions (approximately 108-109 questions for each LBO) were randomly selected. Two high school biology teachers were asked to sort the questions into two groups according to Bloom's taxonomy (1956): (1) Low Cognitive Level (LCL) (questions asked at the knowledge and comprehension levels) and (2) High Cognitive Level (HCL) (questions asked at the level of application, analysis, synthesis, and evaluation).

The second analysis of the fluency of student questions involved the teachers in categorizing the questions into four main groups according to their biological content relationship to the themes of structure, function, concept, and principle.

The agreement between the two teachers on sorting students' questions into the two cognitive levels and four biological content themes provided a measure of the reliability of the procedures for categorizing students' questions. The following values (expressed as percentages) were obtained for the teachers' and students' categorization of the questions in six clusters: questions related to low cognitive level, 77%; high cognitive level, 80%; questions related to concepts, 89%; principles 73%; structures, 86%; function 89%. These measures of reliability values enabled us to use the 656 questions categorized in the above six clusters as a key to sort the rest of the students' questions into their cognitive levels and biological content themes.

Procedure

Classes were assessed at different periods according to the school timetable, a fact which assured random assessment during the learning day. The administration of the tests was undertaken by the researchers. The classroom teachers were present but did not intervene during the entire period. Each student was given a file which included several pages. In the first page, students were asked to provide personal information regarding name, date of birth, gender, and their classroom and grade; the second page included an explanation about the study goals. Students were informed that they would be exposed to different pictures and asked to observe them and to write, at the bottom of each picture, questions about what they would like to learn about the content exposed by the pictures. Students were asked to look carefully at the pictures to write as many questions as they wished in relation to the content they observed. They were informed that all questions would be considered since there were no wrong questions and that their responses would not serve any evaluative purposes.

Following these two pages, six pictures were presented separately, each picture exposing a different LBO. Each file contained six different LBO pictures randomly selected from a total of 30 pictures (5 for each LBO). Every student received one randomly selected file. At the bottom of each picture a title was typed to indicate the content of the picture, but not the LBO to which it belonged. Sufficient space was left for students to write their questions. An additional page was provided for those who needed more space for their questions. Students were allowed 50 minutes for reading the instructions, observing the pictures, and writing their questions.

Results

The 11,435 questions asked by the students were categorized by LBO and were analyzed for cognitive levels (Bloom 1956) and for their biological content themes (Schwab 1966; Klinckman 1970). This analysis was done by using the six clusters obtained in the analysis and categorization of the 656 questions.

A mean score for the number of questions for each LBO by cognitive level, biological content themes, and by grade and gender was obtained for statistical analysis. The mean scores of the number of questions' fluency by their cognitive levels and biological content were treated by three-way analysis of variance followed by MANOVA for main interactions effects between the three independent variables: LBO, grade and gender. Students' mean score of the number of questions fluency by LBO, cognitive level, gender, the main interactions effects, and their F-values are displayed in Table II.

The results show that students from each of the grades asked most of the questions at the low cognitive level. On the low cognitive level significant differences were found between the mean scores of the three grades on the five LBO's. At the high cognitive level students in grade 10 asked significantly more questions at the cellular level and students in grade 9 asked significantly more high cognitive level questions at the community level. Girls asked significantly more questions at the low cognitive level related to organism levels than did boys. There were no differences between the numbers of questions at the high cognitive level asked by the boys and the girls in all six LBO, although girls' mean scores were slightly higher. The F-values obtained by MANOVA support the significant differences presented above in relation to LBO, grade and gender, but do not indicate any interaction effects among the variables. Therefore, we can conclude that the impact of the independent variables (LBO, grade and gender) on question fluency at low and high cognitive level and on the biological content of questions was additive only.

Table III presents the mean scores of the number of the fluency of students' questions on biological content themes by LBO, grade and gender.

From the results presented in Table III, one can see that the fluency of students' questions was higher on the structure and function themes. Fewer questions were asked regarding concepts and very few regarding biological principles. Comparing grades the following results emerged. On the concept theme, tenth graders asked significantly more questions than ninth and eleventh graders in five LBOs but on the function theme grade 11 asked significantly more questions on the cellular, organism, and community levels.

Girls asked more questions on concepts and principles in general, and significantly more on tissue, organ and population. In relation to the structure theme, girls asked more questions than the boys and their mean scores were significantly higher on tissue and organism. On the function theme, boys asked significantly more questions on the cell, organ, and community levels. Table III shows that the results obtained by MANOVA demonstrate significant differences between the scores on the four biological content themes by grade, gender, and LBO. No interaction effects were found among the independent variables investigated except on structure, between grade and gender, and on function, between gender and LBO.

DISCUSSION

The results clearly show that students asked more questions related to organism, population and community. The same pattern was observed in regard to the low and high cognitive levels of the questions. Therefore, one may conclude that students are more able to perceive meaning at LBO which facilitates a more holistic approach. If we consider the fluency of student questions as an indicator of their preferences, then one can see the gap which exists between student choices and the curriculum and textbooks offered in high school biology, which strongly emphasize the molecular, cellular, tissue and organ levels. These LBO represent the areas most studied in biology today, but one may ask if in the heterogeneous schools population, a differential approach in curriculum would not be more appropriate. So different groups of students with different abilities, interest and needs would be offered different LBOs topics in biology. Age, interests, and cognitive abilities can be important factors in students' motivation for learning at a specific LBO. Therefore, consideration should be given as to which LBO might better suit a certain age of students, their interests and abilities: the reductionist or the holistic approach. This approach might be promising in terms of students' motivation and academic achievement.

Studies have shown that students differ in their ability to cope with the reasoning demands of different topics in biology (Lawson & Blake, 1976), in their cognitive preference (Tamir & Kempa, 1978), and in their science subject matter preferences (Lazarowitz & Hertz-Lazarowitz, 1979; Baird, et. al., 1984). One may ask whether these differences should be taken into consideration when biology curriculum and biology textbooks are offered to high school biology students. The requirement for a differential approach to curriculum implementation is highlighted by the gender differences found in the present study. Since we did not investigate the reasons for gender differences we cannot provide clear answers, but it seems that these gender differences in LBO preferences may be a result of different interests due to girls' earlier maturation. Topics appealing to girls should be offered in order to increase their motivation and, subsequently, their academic achievement.

The analysis of students' questions by their cognitive level revealed that most of the questions were at the low cognitive level. Students in grade 11 asked more high cognitive level questions, followed by the students in grade 10. Students in year 9 asked few questions at this level. No differences in question fluency at the high cognitive level were found between boys and girls. It is well known that one of the most emphasized goals in new science curricula is to bring students to a high cognitive level of activity. Their low number of questions at this cognitive level (application, synthesis, anaylysis, and evaluation) attracts our attention to Lawson and Blake (1976) who found that most high school students were still at the concrete operational stage and, therefore, cannot act at the formal reasoning stage. That may be the case with our sample of students; however, this issue was not investigated in this study. Another explanation for the low number of questions at these higher levels might be based on the suggestion of Tamir and Kempa (1978) that teachers and their methods of instruction might influence and determine students' levels of cognitive operation. Students most frequently operate at the low cognitive level because most of the teaching components in the classrooms and examination requirements are at the knowledge level which ask for recall only. Interesting findings in this study show that most of the questions at the high cognitive level were addressed to the cellular, tissue, and organ levels and the frequency of the questions was reduced at organism and population. This reduction can be explained by the fact that eleventh graders who are more mature were those who asked more questions at the higher cognitive level in relation to cell and tissue, while the ninth graders asked more questions at the low cognitive level relating to organism, population, and community. If different LBO can stimulate students to ask questions at different cognitive levels, then the relationships between reasoning ability, the cognitive level of questions, and LBO provide an interesting area of study. These results also may suggest the need to pay heed to Klinckman's (1970) suggestion that the cellular and tissue levels should not be offered to young students. According to Klinckman, students who are not pursuing biology in later years, or those academically poor or young students, should be offered a biology curriculum which emphasizes the levels of organism, population, and community. Other students should be offered all the levels, including molecular and cellular.

Students asked more questions related to concepts and very few related to principles in relation to the four biological content themes. Students from all three grades asked more questions about concepts regarding the cell, tissue, and organ levels than on the other three LBO and tenth graders asked many more than ninth and eleventh graders. Differences between boys and girls were found on concepts related to the tissue and population levels, and on principles related to tissue and organ. These differences might indicate the different interests and needs attributed to gender.

The results regarding structure and function show similar patterns. While structure and function is a basic principle in biology, students tended to ask separate questions about these two themes. These results emphasize that students related more to concepts, less to principles, and related separately to structure and function, but did not perceive any connection between them. If these learning outcomes are a result of the instructional method used by teachers (Tamir & Kempa, 1978), or a result of a combination of teachers' instruction and students' reasoning abilities (Lawson & Blake, 1976) this issue needs further investigation. The fact that students asked separate questions for structures and separate questions for functions and very few on principles, may support the notion that these two themes possible require a formal operational level. Consideration should be given to selecting teaching strategies that will enable students to relate more frequently to biology principles in general and to the structure and function as a single principle.

It is suggested that in the case of a heterogeneous classroom (in terms of students' different abilities, interests, needs, motivation, gender and previous knowledge) different topics within a subject area should be concurrently available. It is clear that this kind of differential curriculum approach calls for alternative methods of instruction and learning. One of these alternatives could be the co-operative method of instruction (Johnson & Johnson, 1978; Lazarowitz et. al., 1985). This method enables students to study different topics within a broader subject in small heterogeneous groups.

TABLE III
Students' Questions Fluency by LBO, Biological Themes, and Gender,
Means and F-Values

Grade	N	Cells	Tissue	Organ	Organism	Population	Community	Total	F-Values
		x	x	x	x	x	x	x	
Concept									
9th	182	3.66	2.90	1.28	0.68	0.67	1.25	1.68	26.06*
10th	293	6.00	5.14	2.40	1.31	1.04	1.40	2.74	7.78*
11th	108	3.62	3.29	0.38	0.78	0.50	0.71	1.48	14.54*
F-Values		2.80**	3.86**	5.35*	NS	NS	NS	3.72**	
Gender									
Boys	188	3.82	2.28	1.23	0.70	0.51	0.93	1.46	6.32*
Girls	400	5.20	4.79	1.93	1.16	1.02	1.32	2.51	20.68*
F-Values		NS	8.71*	NS	NS	4.33**	NS	12.29*	
Principle									
9th		0.34	0.63	0.34	0.16	0.17	0.32	0.32	NS
10th		0 76	0.33	0.58	0.27	0.15	0.58	0.44	5.01**
11th		0.26	0.21	0.06	0.06	0.00	0.71	0.23	3.39**
F-Values		NS	NS	3.41**	NS	NS	NS	6.71*	
Boys		0.54	0.16	0.16	0.11	0.10	0.36	0.22	NS
Girls		0.52	0.52	0.54	0.24	0.14	0.61	0.43	4.87**
F-Values		NS	2.59**	5.86*	NS	NS	NS	7.61*	
Structure									
9th		3.55	4.23	3.47	4.97	2.40	2.82	3.64	2.44**
10th		5.64	7.60	5.50	8.59	4.20	3.38	5.77	7.48*
11th		3.89	5.43	3.38	4.17	1.65	5.10	3.89	2.81*
F-Value		2.23**	6.84*	2.30**	7.00*	5.57*	2.03**	2.63**	
Boys		4.43	4.76	3.39	4.70	2.74	4.32	3.99	NS
Girls		4.72	6.63	5.00	7.54	4.46	3.30	5.10	9.20*
F-Values		NS	4.26**	NS	4.59**	NS	NS	4.52**	
Function									
9th		4.69	4.07	8.66	7.89	4.77	5.36	6.03	6.80*
10th		7.11	5.56	9.68	8.82	5.83	5.30	7.08	7.01*
11th		10.38	4.65	7.67	10.44	6.50	6.58	7.70	NS
F-Values		5.72*	NS	NS	5.42*	NS	3.32**	3.31**	
Boys		7.45	6.32	7.55	7.57	5.03	8.36	6.97	NS
Girls		5.72	4.74	6.69	8.69	5.46	5.62	6.89	13.58*
F-Values		2.35**	NS	4.58**	NS	NS	2.34**	NS	

MANOVA - Interactions Effects and F-Values

	Concept	Principle	Structure	Function
Grade	12.38*	2.89**	15.78*	4.17**
Gender	11.75*	6.17*	4.48**	2.66**
LBO	37.57*	4.24**	9.95*	9.03*
Grade x Gender	NS	NS	3.65**	NS
Grade x LBO	NS	NS	NS	NS
Gender x LBO	NS	NS	NS	2.44**
Grade x Gender x LBO	NS	NS	NS	NS

* P<.01
** P<.05
NS = Non significant

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PUPILS' LEARNING OF SCIENCE IN PRIMARY SCHOOLS: A SYSTEM-LEVEL INVESTIGATION

N. Cranston & R. McAllister

INTRODUCTION

Background to the Development of the Primary Science Project

A curriculum development project was initiated in 1975, following a study by Varley (1975) which suggested that the aims of the 1966 Queensland Primary Science Syllabus were not being adequately met. That Syllabus emphasised that science was basically a 'way of learning' and that it should be presented as a process whereby new knowledge was uncovered. However, the 1975 study found that only about one-third of science classes engaged in problem solving, pupil use of apparatus and similar activities which characterise science as a process of investigation, and which require pupils to obtain first-hand experience with scientific investigation. It was decided that the introduction of a new syllabus alone would do little to improve the teaching of science. Additional input to the nature and composition of the project was provided by an evaluation conducted by Crocker (1979).

Features of the Primary Science Project

The Project is made up of a number of interrelated elements:

- a new syllabus document - Syllabus and Guidelines for Teachers of Primary Science;
- in-service materials - Science Curriculum In-service Modules (SCIM);
- curriculum materials - Sourcebooks (one for each Year level) and other materials; and
- in-service initiatives - e.g. use of regional advisory teachers (these were phased out in 1984), together with a ripple-dissemination model within schools.

The Syllabus is designed to provide a broad framework for a science program, and emphasises that primary science should be taught using an active 'hands-on' approach. The five elements considered to be essential to an effective science program are:

- process skills;
- manipulative skills;
- positive attitudes;
- concepts; and
- 'hand-on' activites.

The interrelatedness of the five elements is evident in the Sourcebooks and emphasised in the Syllabus. One representation of this interrelatedness in the teaching-learning process and the contribution of other factors to pupils' learning of science is illustrated in Display 1.

THE INVESTIGATION

In 1983, the Departmental Science Syllabus Committee requested that an investigation of the learning of science in primary schools should be undertaken. This decision was taken in response to a belief among those responsible for its initiation, development and implementation that the project had had an impact on science education in primary schools. In addition, other curriculum areas were interested in obtaining information on the implementation model adopted for science.

The general aims of the investigation were:

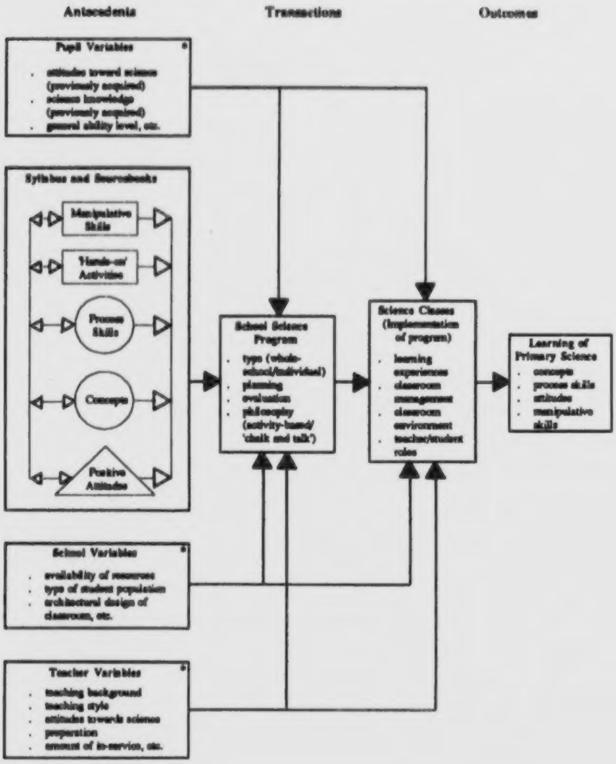
- to provide information and instrumentation for monitoring the learning of science in primary schools; and
- to establish some benchmarks of pupil performance for possible future investigation.

Decisions concerning those aspects of the learning of science to be investigated were arrived at from an analysis of the materials produced by the Project, such as the Syllabus, in-service modules and Sourcebooks. In terms of pupil performance, it was decided that science Process Skills and Concepts were of particular significance. Other information, such as pupils' attitudes to science and classroom practices, were also important. Year 5 and Year 7 were selected as the target Years.

COLLECTION OF INFORMATION

Following major reviews of the literature and the documentation of similar projects in the United Kingdom and Canada, it was decided that instrumentation needed to be developed for use in the investigation in each of three areas: pupils' attitudes to science and to learning science; Process Skills; and Concepts.

Display 1: Model for the Learning of Science in Primary Schools


Antecedents
Transactions
Outcomes
Pupil Variables *
. attitudes toward science (previously acquired)
. science knowledge (previously acquired)
. general ability level, etc.
Syllabus and Sourcebooks
Manipulative Skills
'Hands-on' Activities
Process Skills
Concepts
Positive Attitudes
School Science Program
. type (whole-school/individual)
. planning
. evaluation
. philosophy (activity-based/ 'chalk and talk')
Science Classes (Implementation of program)
. learning experiences
. classroom management
. classroom environment
. teacher/student roles
Learning of Primary Science
. concepts
. process skills
. attitudes
. manipulative skills
School Variables *
. availability of resources
. type of student population
. architectural design of classroom, etc.
Teacher Variables *
. teaching background
. teaching style
. attitudes towards science
. preparation
. amount of in-service, etc.

*Contextual variables.

- Attitudes: The desirable attitudes listed in the Syllabus and the specific outcomes given for particular Sourcebook topics were broadly grouped into two categories - those related to feelings about learning science and those concerning science beyond the classroom. Each group contained approximately 10 items to be included in the Pupil Questionnaire. Additional information on, for example, classroom practices was also sought from pupils. A Teacher Questionnaire, with some sections paralleling the Pupil Questionnaire was also developed. It was intended that, as well as providing important information in its own right, the Teacher Questionnaire would assist in interpretation of pupil performance data.
- Process Skills: The Syllabus lists two major groups ('basic' and 'integrated') containing 13 named processes. The study assumed that aspects of 'communicating' would be involved in any test of the other 12 processes. Forty-nine tasks relevant to five clusters of Process Skills were identified for testing. (These tasks are documented elsewhere [Cranston, 1988]).
- Science Concepts: The Syllabus specifies five 'areas' in which children should be given the opportunity to develop concepts at each year level. For the purposes of the investigation, 18 general principles were identified to clusterrelated Concepts. Information on the development of children's understanding of those principles, assessed from their performance on 63 specific tasks, was sought (Cranston, 1988).

The process of development, review and refinement of the instrumentation in these areas was a major task. Contributions to the process came from officers of the Department's Research and Curriculum Branches, panels of teachers and others considered expert in the field. A series of trials, both formal and informal were conducted to assist in the process. An important element of these trials was extensive field work in schools with groups of students and teachers.

In consideration of both the issues to emerge from the trialling and other important factors, critical decisions about the number of tests, and the type and number of items comprising the tests were taken. In summary, these were as follows:

- Item type: The intended outcomes of the science curriculum project were of a very specific type. Children were expected to develop thinking skills and scientific understanding rather than merely rote-learning sets of facts. As such, it was felt that many of the desired pupil abilities could not be reliably measured by items which required only a choice from among pre-determined options. Hence, pupils were given the opportunity to think through the task and to write answers in their own words. This resulted in the item pool containing many items of the open-ended type.

- Number of items: The trials with pupils in Year 5 and Year 7 showed that fatigue became a significant problem after about 30 minutes work on items of the type to be used. This imposed a maximum upper limit of approximately 15-18 items per test instrument.
- Number of Tests: The upper limit on items per Test and the number of tasks to be assessed required that several parallel forms of each instrument were needed to adequately sample the expected outcomes. Hence, at each Year level, four forms of each of the science Process Skills and Concepts Tests were constructed.

  (Note: The four forms at each Year level contained a number of common (anchor) items. In addition, Tests at Year 5 and Year 7 also contained a number of common (marker) items).

  In summary, instrumentation for the investigation comprised:
- Process Skills Test (15-18 items) - four forms at each Year level - approximately 30 minutes to complete.
- Concepts Test (15-18 items) - four forms at each Year level - approximately 30 minutes to complete.
- Pupil Questionnaire - approximately 15 minutes to complete.
- Teacher Questionnaire - approximately 20 minutes to complete.

  This information is summarised in Display II.

Display 2: Science Information Summary

About	Type of Information	Source of Information	Method of Gathering Information
The Pupil	• Concept performance	Pupil	Concept test
	• Process Skill performance	Pupil	Process Skill test
	• Overall science performance	Teacher	Teacher questionnaire
	• General ability	Teacher	Teacher questionnaire
	• Interest in science	Teacher/Pupil	Teacher/Pupil questionnaire
	• Science attitudes	Pupil	Pupil questionnaire
Science Classroom	• Classroom practices - emphases, teaching-learning strategies	Pupil Teacher	Pupil questionnaire Teacher questionnaire

Following the development of the instrumentation, essential elements of the investigation have consisted of:

- Selection of five per cent random samples of pupils (approximately 1600) at each of Year 5 and Year 7 levels to participate in the investigation.

- Testing of pupils with each pupil in the sample completing a Process Skills Test, a Concepts Test and a Questionnaire (total time approximately one hour, 15 minutes). (It was suggested that the instruments be administered over two days with appropriate rest period for pupils). Classroom teachers in the selected schools administered the instruments with the aid of an Administration Manual. Teachers also completed a Questionnaire.
- Marking of Tests - because of the open-ended nature of some of the Test items, a panel of 20 teachers was convened to carry out the marking under the supervision of relevant officers of the Research and Curriculum Services Branches.
- Data preparation and analysis.
- Reporting of information.

SUMMARY FINDINGS TO DATE

Analysis of the considerable amount and type of information from the investigation is continuing. To date, two aspects of the data have been studied in some detail. The first is concerned with the performance of pupils at each of Year 5 and Year 7 on each of the Concepts and Process Skills items. The second is concerned with science classroom practices and attitudes to science.

I. As a first step, the pupil performance information, prepared specifically for the science committee which commissioned the investigation, has been summarised by way of item summary proformas (Display III). For this aspect of analysis of the data, it was considered important not to lose potentially valuable item performance data through a coded marking process (i.e. correct, incorrect, etc.). Hence, the 'response distribution' does not involve an actual 'marking' of the item. (Marking of items is currently being done to address other questions of interest in the investigation).

A review of the information provided in the item summaries reveals a number of general findings of interest. They include the following.

Crucial Role of Item Format

Children at both Year levels scored markedly better on items or parts of items requiring a choice of response compared with those demanding a constructed response. The comparison was particularly obvious on two-part questions where the child was required to 'select' in one part and 'explain' in the following part.

Display 3: Item Summary Proforma

ITEM: ID Number

Test Location

5A	5B	5C	5D	7A	7B	7C	7D

Reproduction of item as presented to children, with information for markers added

Concept: Abbreviated explanation of the concept/process skill tested.

Group: Specific Target Group for this item (e.g. Year level, sex).

Response Distribution

Response	% Choosing
Percentage of Target Group responding according to criteria listed	%
	%
	%
	%
	%
	%
	%
	%
	%
	%
	%
	%

Discussion of Item

Marker Ratings:
n = Number of markers providing information.

Difficulty ☐
Importance ☐
five point scale

Comment/Summary:
As made by markers, referring to specific Target Group.

Other Comments:
For comments of Primary Science Committee.

Marking Scheme: Comments, if necessary, to further explain the marking as already indicated above and to the left.

This outcome vindicates the item design decision not to rely solely upon multiple-choice (or similar closed) format items. Such items may have led to an over-estimation of the level of performance by pupils.

Use of Precise Terminology

An important assumption underlying the curriculum of the Primary Science Project is that teachers will use, and that children will understand specific scientific terminology such as, for example, 'inference' and 'hypothesis'. Items in which such terms were important cues were, in general, done less well when compared with similar items without the terms.

Use of Numbers

Many of the items on which children performed least well involved the manipulation of numbers. A common pattern would seem to be that the pupil selected the wrong algorithm to model the physical situation to begin with, but then was able to complete the computation correctly.

A related point concerns performance on items involving the identification of patterns and trends in a given (incomplete) set of data. The 'incorrect' answers provided in such items suggested that many children sought precise patterns in the individual digits within numbers rather than examining their magnitudes and offering appropriate 'best estimates'.

Reliance Upon Pictorial Content

There is a suggestion from inspection of the clustering of raw scores, and from limited subsequent interviewing, that children at both Year levels relied more upon the pictorial than the written component of the questions to arrive at their responses.

Treatment of Sequences and Cycles

Items which involved a dimension of change with time (e.g. energy conversions, food chains, life cycles) appeared to cluster in difficulty independently of their content. Identification of a 'beginning' point in these items would appear to be a particular problem for many children.

Basic and Integrated Processes

The curriculum under review in this investigation followed the distinction of identifying two categories of process (skills), one of which was assumed to be appropriate only for older children. (In this case, they are referred to as the Integrated Processes -

Years 5-7). No such clear differentiation has yet emerged from inspection of the available data. It would appear that the range of difficulty of individual items within each category is as great as the difference across categories.

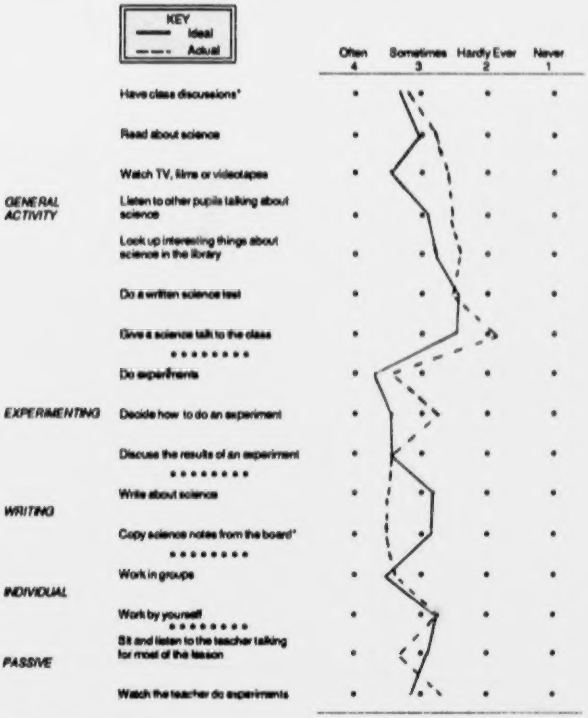
Further analysis of these and many related issues is continuing, e.g. comparisons across and within the Process Skills and Concepts categories.

II. A review of the information to date on science classroom practices, and pupils' attitudes to science, science lessons and science activities reveals a number of interesting findings. Displays IV to VI provide the dimensions and items of the three parts of the Pupil Questionnaire as well as illustrating some of the trends in the data discussed below.

(a) Classroom Practices (Display IV)

Pupils were asked to respond as to their 'actual' and 'ideal/preferred' classroom experiences. Teachers completed the same questionnaire.

Display 4: Classroom Activities (Ideal/Actual)



*May fall into other categories.

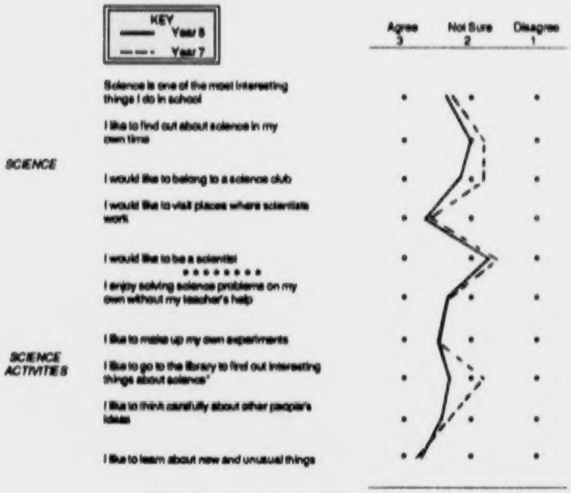
Actual Classroom Practices

- Similar patterns of activities were reported by pupils at both Year levels.
- Year 7 pupils indicated they generally did 'activities' less frequently than Year 5 pupils, except in the area of experimenting.
- Writing, experimenting, class discussions and sitting and listening to the teacher talking most of the lesson were the major activities reported by pupils in the science classroom.
- Similar general patterns were reported by the teachers, although teachers indicated the existence of more class discussions, less copying of notes from the board, less sitting and listening to the teacher talking for most of the lesson than was indicated by the pupils.
- Teachers reported similar patterns across Year levels with the exception of more discussion of results of experiments by pupils at Year 5.
- Similar patterns of activities were reported by both boys and girls at both Year levels, although girls reported fewer general activities (watch television, films, videotapes), more discussion of the results of experiments, more work in groups and more work by themselves.

Ideal and Actual Classroom Practices

- Similar patterns of preferred activity were indicated by pupils at both Year levels.

Display 5: Positive Attitudes Towards Science and Science Activities (Year Level)

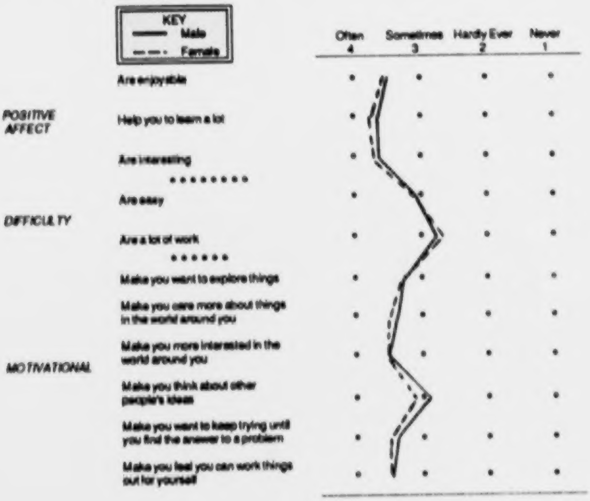


- Year 5 pupils indicated they would prefer more types of science activities (e.g. reading about science and watching television, films and videotapes), more experimenting, more group work, less writing and less passive activities (e.g. sitting and listening to the teacher talking for most of the lesson).

(b) Attitudes Towards Science and Science Activities (Display V) The following findings are noteworthy.

- Similar patterns were reported by pupils at both Year Levels, although Year 7 pupils were generally less positive.
- Pupils indicated they would particularly like to visit places where scientists work, to make up their own experiments and to learn about new and unusual things.
- Pupils generally indicated they were not sure whether they would like to be a scientist, or belong to a science club.
- Girls, at both Year levels (but particularly at Year 7), were less positive than the boys on most items. Boy/girl differences were greater at Year 7 than Year 5.

Display 6: Attitude to Science Lessons (Sex) (Year 5)



(c) Attitude to Science Lessons (Display VI)

The following findings are noteworthy.

- Overall, a similar pattern of positive attitudes towards science lessons was expressed by pupils at both Year levels, although Year 7 pupils were generally less positive.

- In particular, items most strongly endorsed by pupils included that science lessons help them learn a lot, are enjoyable, interesting, make you more interested in the world around you and make you want to keep trying until you find the answer to a problem.
- Girls at Year 5 were generally more positive than boys in their attitude to science lessons - this situation was reversed in many areas at Year 7.
- In particular, negative 'shifts' for girls from Year 5 to Year 7 occurred for items such as make you want to explore things, make you want to keep trying until you find the answer to a problem - generally, this shift occurred in the 'motivational' subcategory.

SUMMARY

The investigation into pupils' learning of science in primary schools has resulted in the development of instrumentation consistent with the aims and philosophy of the Primary Science Project. This instrumentation has been used to gather information on pupil performance on Process Skills and Science Concepts as well as information on pupil and teacher attitudes to science and other aspects concerning the learning of science. While analysis of the available data is continuing, review of the processes of the investigation and its early findings provide information for consideration by curriculum developers, test developers, those interested in system-level monitoring of key curriculum areas and teachers. The investigation is also likely to provide valuable data for the review of the instrumentation used in the study.

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THE "PUPIL-AS-SCIENTIST" METAPHOR IN SCIENCE EDUCATION

Colin Gauld

INTRODUCTION

A metaphor is a figure of speech in which one thing (the primary pole) is said to be another (the secondary pole). It functions as the user emphasises and develops the implications of those features which represent similarities between the two poles while suppressing or ignoring features representing differences between them (Pope & Gilbert, 1983).

The "pupil-as-scientist" metaphor has been around for a long time in the science education literature although some of its functions appear to have changed in recent years. This paper is an exploration of some of these functions.

TWO FACES OF THE METAPHOR

In the science education literature the "pupil-as-scientist" metaphor has been associated with two similarities between pupils and scientists which, though often promoted together, are conceptually independent. At different times emphasis has been placed on one or other of these aspects.

In the first place the metaphor has directed attention to a particular approach to developing in pupils the processes and spirit of science which were believed to be of benefit to everyone. For example, Blough (1960) claimed that:-

> "Much of children's science study is aimed at finding out *what* takes place, *what* happens, *how* things happen, under *what* circumstances things happen. Such observations lead to descriptions of events and things. Scientists and children, too are engaged in making accurate descriptions of things as they are ... through working in the ways that scientists work they will learn how knowledge is verified, confirmed or corrected" (pp. 114, 115).

Writing in the same year as Blough Jerome Bruner claimed that "the school boy learning physics *is* a physicist" (Bruner, 1960, p. 14; Bruner's emphasis). Ten years later Nay and Crocker stated that "if students learn science in an appropriate mode (e.g. by 'imitating' the scientist) they will acquire the desired affective attributes" (Nay & Crocker, 1970). This is a claim that the best way to teach scientific skills and attitudes is to place the student in the role of a scientist.

This emphasis, which was a dominant one in earlier times has continued into the 1980's in teacher education literature (e.g. Simpson & Anderson, 1981, pp. 1, 111). However, a significant section of the contemporary science education research community has continued and elaborated another use of the "pupil-as-scientist" metaphor in its writing. In this the emphasis is not on the role pupils adopt in the classroom but on the similarities which are presumed to exist between the cognitive functioning of pupils in their everyday life and that of scientists in their work. In 1947 it was pointed out that "the spontaneous drive and curiosity of children in exploring their environment are not dissimilar to the drive and curiosity of scientists" (Henry, 1947, 63). By others parallels were drawn between what children do in learning science and what scientists do their work. For Bruner "intellectual activity anywhere is the same whether at the frontier of knowledge or in a third-grade classroom....The difference is in degree not in kind" (Bruner, 1960, p. 14).

A more recent and explicit expression of this metaphor is found in the widespread use of the term "children's science" (Gilbert, Osborne & Fensham, 1982) and in Driver's The Pupil as Scientist? (1983). For those who are part of the alternative frameworks movement the emphasis on placing the student in the role of the scientist in order to teach scientific skills and attitudes is totally absent (Millar & Driver, 1987).

ELABORATION OF THE METAPHOR

In this literature the analogy occupies a more central role and is developed with greater attention to both similarities between scientists and learners and differences between them (see, for example, Gilbert, Osborne & Fensham, 1982; Osborne & Freyberg, 1985).

Among the most commonly mentioned similarities are that scientists and children both:

- possess interest in a wide variety of objects and events,
- attempt to make sense of the world,
- view the world through strongly held pre-conceptions or beliefs,
- gather facts, develop explanations or hypotheses, make predictions, and test their ideas,
- develop theories which are coherent and rational within their focus of application, and
- change their major ideas slowly.

Differences between pupils and scientists which are frequently mentioned include the following:-

- children's understanding of particular phenomena not always the same as the scientist's,
- the purposes and intentions of children and scientists often differ,
- children are less conscious of their thought processes and procedures than scientists,
- children's ideas are often less comprehensive than scientists,
- children's ideas are dominated by what they perceive while those of scientists often refer to abstract entities, and
- children use everyday language while scientists use specially constructed technical language.

SOME FUNCTIONS OF THE "LEARNER-AS-SCIENTIST" METAPHOR

Apart from reference to the similarities and differences between children and scientists there is not always explicit discussion of the purpose of the metaphor in the science education literature. It simply constitutes part of the rhetoric of science education. However, it is possible to identify a number of reasons for using it.

(a) The statement that "the pupil is a scientist" is often used as a slogan to attract attention to a claim that is likely to be thought outrageous but which is worthy of consideration. The title of Driver's (1983) book seems to serve this function.

(b) The "pupil-as-scientist" metaphor focuses attention on those components of scientific activity - possession of prior beliefs or theories, expectations or predictions on the basis of these theories, assimilation of experience to these beliefs, response to anomalies where expectations are not fulfilled - which pupils are considered to possess from a young age. In the classroom these processes and the beliefs and attitudes associated with them are developed in particular directions from existing skills and attitudes rather than established from nothing (Millar & Driver, 1987) as in the alternative use of the metaphor.

(c) The notion of "children's science" is a reflection of the belief that these ideas "provide a sensible and coherent understanding of the world from the child's point of view" (Gilbert, Osborne & Fensham, 1982) and that the phrase "accords to children's views the status that society frequently gives to science" (Gilbert & Watts, 1983). In this role it replaces the more negative connotations of "misconceptions". Thus the metaphor associates some of the esteem of science with pupils' ideas (Newman, 1978).

(d) The idea that the pupil is a "scientist" points to the extensive research in the history, philosophy, psychology and sociology of science as a possible source of information for understanding conceptual change in the classroom. Strike and his colleagues (e.g. Strike & Posner, 1985) have adopted the implications of this metaphor in turning to the philosophy of science for general conditions governing conceptual change in science students which occurs as a result of teaching.

(e) The alternative emphasis on placing the pupil in the role of the junior scientist in order to learn scientific skills and attitudes largely presumes an empiricist epistemology in which the pressure of experience is the major determinant of the knowledge or beliefs which people develop. The more recent emphasis signals a change to a constructivist epistemology in which experience is assimilated to prior expectations and beliefs and can lead to quite different outcomes to those expected by an outsider (such as the teacher). In this case the purpose of the elaborated metaphor is to persuade others about the validity in education of an epistemology which has been prominent in studies of scientific activity since about 1960.

A NETWORK OF RELATED METAPHORS

The "pupil-as-scientist" metaphor is widely used in the recent science education literature but it can also be considered as part of a larger network of related metaphors.

A figure of speech found in the psychological literature is the "child-as-adult" metaphor. In 1935 Piaget discussed and criticised the view of education that "treated the child, in effect, as a small adult, as a being who reasons and feels just as we do while merely lacking our knowledge and experience" (Piaget, 1970, p. 159). In his criticism of this view Piaget retained the analogy between the child and the adult but reversed the similarities and differences.

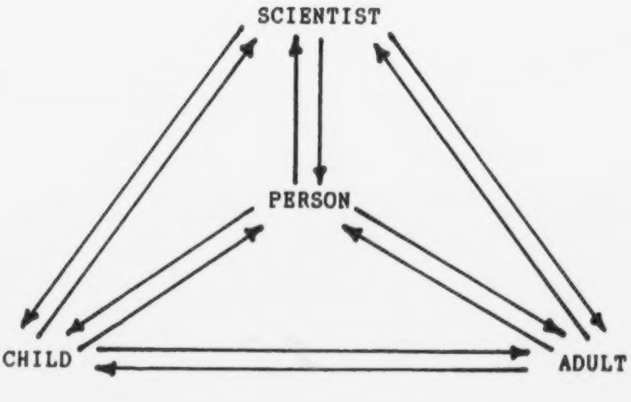
> "Traditional pedagogy attributed to the child a mental structure identical to that of the adult, but a different mode of functioning (Piaget, 1970, p. 152)... In fact it is the contrary that is true. The intellectual and moral structures of the child are not the same as ours ... but with regard to mental functioning, the child is in fact identical with the adult (p. 153)...
> It is undeniable, from the functional point of view, that the child is already striving toward coherence: that is in the nature of all thought, and the child's obeys the same functional laws as ours. But the forms of coherence that satisfy the child are not the same as those we require" (p. 164).

The resulting relationship between child and adult originally drawn by Piaget possesses many of the characteristics of that between the child and the scientist in the recent science education literature.

In the writings of George Kelly the notion of "man-the-scientist" (Pope, 1982; Pope & Gilbert, 1985) is used to assist in the understanding of human behaviour by focussing on the scientist-like aspects of people.

Central to the relationships discussed above is the notion of a "person". The similarities between the child, the adult and the scientist are related to the fact that they are all persons (see Figure 1) who function, by and large, in a rational manner (Strike & Posner, 1985).

FIGURE 1. A broader network of metaphors



Metaphors draw attention to similarities between their two poles and may fruitfully be reversed so that, as well as thinking of the pupil as a scientist, one can consider the implications of thinking of the scientist as a child or as a learner. In this case what is known about cognitive processes in children can be used to assist in understanding scientific activity. For example, Kelly saw scientists in this light:

> The nice thing about hypotheses is that you don't have to believe them. This, I think, is a key to the genius of scientific method. It permits you to be inconsistent with what you know long enough to see what will happen. Children do that. What is wonderful about the language of hypothesis is its refreshing ability to free the scientist from the entangling consistencies of adulthood. For a few precious

> moments he can think again like a child, and, like a child, learn from his experience (quoted in Pope & Gilbert, 1985, p. 26).

It is possible that recent research into how children learn science has persuaded a number of teachers and others to abandon the widely held empiricist view of science and adopt a more constructivist perspective.

In his study of the development of Darwin's thought Gruber (1974) referred to its "childlike" characteristics. He suggested that, although at that stage little had been done to study the growth of a new point of view, the work of Piaget and his colleagues on the development of thinking in young children might show how such a study could proceed (Gruber, 1981, pp. 4, 5). It is interesting to note that much of the recent work in the psychology and sociology of science has focused on the nature of scientists as persons rather than emphasising those qualities presumed to set them apart from the rest of mankind.

CONCLUSION

The language used in the science education literature often serves the explicit function of presenting information and making cases but it also conveys implicit messages and points to links outside the technical framework of science education. The "pupil-as-scientist" metaphor is embedded in a rich network of associated ideas only some of which have been exploited in research in this and other areas.

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'PRODUCING AND CHOOSING CHEMISTRY TEXTS:
THERE ARE BETTER WAYS'

John Edwards, Joanna Stewart, Scott Ashton

INTRODUCTION

For most teachers and students, the choice of the text to be used in the classroom has a significant impact on the curriculum delivered. Teachers use a variety of methods to choose their texts. Some use reviews from journals, some respond to representatives and advertising, some rely on recommendations from respected peers, some use physical or mental checklists, and some attempt analyses. For teachers wishing to analyse texts in some depth, little help is available.

Eraut et. al. (1975) reviewed the then-available procedures for text analysis. They offered little to help the teacher. Eraut then proceeded to develop an elaborate analysis scheme. This scheme required considerable teacher training for effective use, was very time-consuming, and still dealt mainly with surface features of the text. In Australia, the Curriculum Development Centre prepared a review of junior secondary science texts (Goodrick, 1979). While this review did include readability measures and an estimate of Piagetian level, it still remained essentially a superficial analysis.

Since the mid 1970's there has been a slowly increasing awareness of the importance of analysis of curriculum materials. Researchers such as Marshall (1979), Standal (1981), Clewell and Clifton (1983), Knutton (1983), Muther (1985), Blosser (1986) and Leonard (1987) provide insight into a range of approaches to materials analysis.

Edwards and Dall'Alba (1981) describe the development of the Cognitive Demand Scale for the analysis of science materials. Since that time the Cognitive Demand Scale has undergone further trialling and revision. The present form of the Scale (Dall'Alba and Edwards, 1982) has been used to analyse a wide range of science texts in current usage.

The research reported here is an analysis of three widely-used senior Chemistry texts using the Cognitive Demand Scale, the cloze readability measure, and feedback from students through questionnaires.

The Texts

The texts, or perhaps more properly 'programs', analysed here are: 'Chemistry: Experimental Foundations' (Parry et. al., 1976), probably the most widely used Chemistry text over the last ten years; 'Elements of Chemistry. Earth, Air, Fire and Water' (Bucat, 1984), the major recent development by the Australian Academy of Science; and, 'Chemistry' (Wilbraham et. al., 1987), a program from Addison-Wesley.

Readability

The readability of each of the texts was analysed using the cloze procedure (see, for example, Thelen, 1974). Cloze procedure has been used here rather than the more commonly used semantic measures such as the Flesch or Fry Readability Formulae which rely on syllable counts and sentence length. Cloze procedure is seen as being a better indicator for teachers as it measures functional readability. As expressed by Kirkwood and Wolfe (1980):

> cloze procedure measures the overall concept level and the overall syntactic and semantic processing that must be employed in reading and understanding the passage (p4.)

As used in this research, cloze procedure involved the systematic deletion of every fifth word and replacing each with a fifteen character blank line. Each sample passage consisted of an intact sentence at the start, a passage with 50 blanks, and an intact sentence at the end. Students were then asked to fill in the blanks and only exact word replacements were accepted.

Matched samples were taken from each of the three texts in six topic areas: the mole; nuclear fission; oxidation-reduction; collision theory; alkanes; and kinetic theory. Two hundred grade 11 and 12 students in two co-educational secondary schools were used for the tests over a two-year span. In the first year each student did three samples on different topics from one particular text. In the second year students did three samples from the same topic across the three books. In order to prevent sequencing effects each one third of the samples were done in a different order.

The results from the two different testing approaches produced very similar results and so the results were combined. Table 1 presents the readibility scores for each text. A total of 595 cloze tests make up the data, with 45% of these being completed by grade 12 students. The guidelines of Bormuth (1967) and Thelen (1974) have been used: a cloze score of 0-39% corresponds to 'frustration level'. 40-60% corresponds to 'able to be used with teacher guidance', and 61-100% means 'able to use independently'.

Table 1 Cloze Readability Scores for Three Chemistry Texts

TEXT	PERCENTAGE OF STUDENTS WITHIN EACH SCORING RANGE		
	0-39% (Frustration Level)	40-60% (Use with Teacher Guidance)	61-100% (Independent Use)
'Experimental Foundations'	40%	44%	16%
'Elements of Chemistry'	25%	60%	15%
'Chemistry"	25%	55%	20%

As can be seen from Table 1, both of the newer texts have significantly less students at frustration level than does 'Experimental Foundations', however there are still 25% of the students sampled at that level. Also, only 20% of students were at the independent usage level with the 'Chemistry' text which rated best in this respect of the three texts. It is important to note that for each topic the introductory section of the text was chosen. This allowed easier matching for the between-text comparison. However, these sections are generally conceptually easier and contain few symbols or formulae. As such, the readibilities reported here are generous, while providing useful between-text comparison.

Cognitive Demand

The cognitive demand for the objectives, learning tasks and evaluation items was analysed for each text using the Cognitive Demand Scale (Dall'Alba and Edwards, 1982). The categories used in the Scale are listed in Figure 1. The development of the Scale is described in Edwards and Dall'Alba (1981). There are 39 categories in the scale. Level 1, the lowest level, includes tasks requiring the performing of simple operations on data which are readily available to the senses or stored in memory. Such tasks deal with concrete objects or phenomena and do not require the generation of new ideas. By contrast, level 5 tasks require analysis and/or synthesis and are abstract. They demand the generation of ideas which are original for the student. The data to be operated on are not available in a readily usable form, so that it is necessary to transform them in accordance with the purposes of the task.

The sampling procedure used in this study involved for each component at least the minimum number (20 samples) outlined in the Cognitive Demand Scale. In most cases a much broader sampling regime was used. In sampling, laboratory exercises and other components of the program, for example Skills - Practice exercises, were incorporated with the learning tasks in a ratio in keeping with that recommended in the teacher's guide. End-of-chapter questions and other test booklets were combined to form the evaluation sample.

Figure 1. The Scale of Cognitive Demand

LEVEL 1.

1.1 RECALL OR MEMORISE SPECIFICS
1.2 ASSIMILATE INFORMATION
1.3 SIMPLE MEASUREMENT
1.4 OBSERVE
1.5 SIMPLE COMPARISON
1.6 SIMPLE RECORDING
1.7 FOLLOW A SIMPLE SET OF INSTRUCTIONS
1.8 OBSERVE WITH DISCRIMINATION

LEVEL 2.

2.1 RECALL OR MEMORISE PROCEDURES, PROCESSES, RULES OR PRINCIPLES
2.2 SIMPLE CLASSIFICATION
2.3 DEMONSTRATE USE OF EQUIPMENT
2.4 UNDERSTAND A DIRECT, PHYSICAL MODEL
2.5 TRANSLATE
2.6 SUMMARISE

LEVEL 3.

3.1 RELATE
3.2 DEVELOP AN OPERATIONAL DEFINITION OR SIMPLE CONCEPT
3.3 SIMPLE APPLICATION
3.4 SIMPLE EXTRAPOLATION
3.5 COMPARE ON STATED CRITERIA
3.6 IDENTIFY DISCRIMINATING CHARACTERISTICS

LEVEL 4

4.1 INTERNALISE A CONCEPT
4.2 APPLY A RULE OR PRINCIPLE
4.3 CLASSIFY
4.4 SIMPLE HYPOTHESISING
4.5 COMPLETE AN EXPERIMENTAL DESIGN
4.6 UNDERSTAND A MODEL OF AN ABSTRACTION

LEVEL 5

5.1 CONSTRUCT A MODEL OR OTHER REPRESENTATION
5.2 GENERATE RELEVANT CRITERIA
5.3 EXTRAPOLATE
5.4 GENERALISE
5.5 HYPOTHESISE
5.6 ISOLATE VARIABLES
5.7 DESIGN AN EXPERIMENT OR PIECE OF EQUIPMENT
5.8 ISOLATE INFERENCES OR ASSUMPTIONS
5.9 INTEGRATE

LEVEL 6

6.1 DEVELOP OR EXPLAIN A CONCEPT OF AN ABSTRACTION
6.2 LINK A MODEL WITH REALITY
6.3 ASSESS THE IMPACT
6.4 EVALUATE

FIGURE 2: COGNITIVE DEMAND LEVEL FREQUENCIES

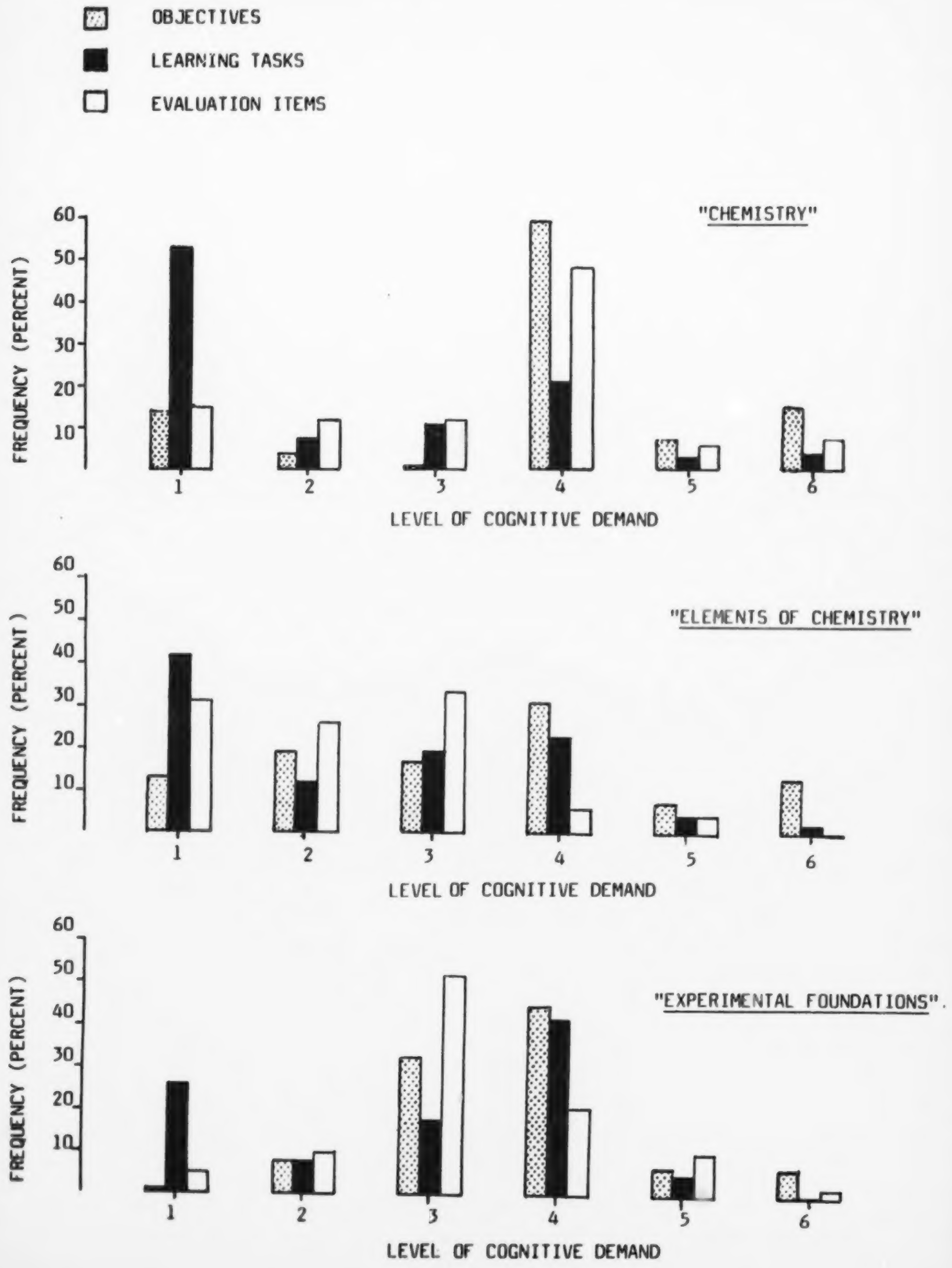


Table 2. Cognitive Demand Level Frequencies

	PERCENTAGE FREQUENCY OF EACH LEVEL					
'Experimental Foundations'	Level 1	2	3	4	5	6
Objectives	1	8	33	45	6.5	6.5
Learning Tasks	26	8	18	43	5	0
Evaluation	5	10	53	21	10	1
'Elements of Chemistry'	Level 1	2	3	4	5	6
Objectives	13	19	17	31	7	13
Learning Tasks	42	12	19	22	4	2
Evaluation	31	26	33	6	4	0
'Chemistry'	Level 1	2	3	4	5	6
Objectives	14	4	1	59	7	15
Learning Tasks	53	7	11	21	3	4
Evaluation	15	12	12	48	6	7

Table 3. Cognitive Demand of Learning Tasks

'EXPERIMENTAL FOUNDATIONS'		'ELEMENTS OF CHEMISTRY'		'CHEMISTRY'	
Cog. Demand Level	Frequency (%)	Cog. Demand Level	Frequency (%)	Cog. Demand Level	Frequency (%)
4.1	35%	1.2	21%	1.2	31%
3.3, 1.2	17%	3.3, 4.1	11%	4.1	25%
2.1, 4.2	5%	1.1	8%	1.1	6%
1.1, 1.6, 1.7, 4.6	3%	4.2	6%	1.3, 3.3, 4.6	4%
1.8, 2.5, 3.6, 5.1, 5.5, 5.6	1.5%	1.7	5%	1.4, 1.6, 1.7, 1.8	3%
		2.1, 2.5, 3.5	4%	2.1, 4.2, 5.7	
		1.6, 2.4, 3.6, 5.5	3%	2.3, 4.4, 5.8, 5.9	1.5%
		1.3, 1.5, 4.3, 4.6	2%		
		1.4, 1.8, 3.2, 4.4, 6.1, 6.3	1%		
65 categorisations from 20 pages		106 categorisations from 23 pages		71 categorisations from 22 pages	

The resulting analyses are presented in Table 2 and Figure 2. They reveal clear differences between the texts. For all three texts the objectives are at a more demanding level than the learning tasks provided or the evaluation items. Both 'Experimental Foundations' and 'Chemistry' have evaluation items which are more demanding than the learning tasks, whereas for 'Elements of Chemistry' the evaluation items are at about the same level as the learning tasks.

'Chemistry' has the most demanding objectives, with the majority (59%) being at level 4. 'Elements of Chemistry' has the least demanding objectives, again with a concentration at level 4, but with a more even overall distribution than either of the other texts. 'Experimental Foundations' has 78% of its objectives at level 3 or 4. Both 'Chemistry' and 'Elements of Chemistry' have much greater proportions of their objectives at level 6 than does 'Experimental Foundations'.

Table 3 lists the cognitive demand levels for the learning tasks in the texts. 'Experimental Foundations' is much more demanding than the other two texts, which are similar. One can see that the same categories dominate each text. The five most common categories: 1.2, 4.1, 3.3, 1.1 and 4.2 account for 77% of the learning tasks in 'Experimental Foundations', 57% in 'Elements of Chemistry' and 70% in 'Chemistry'. By adding the next three most common categories: 4.6, 2.1 and 1.7, the proportions become 88%, 68% and 80% respectively. In the sample used here, of the 39 categories in the Cognitive Demand Scale 24 were not found in the learning tasks provided by 'Experimental Foundations', 22 were not found in 'Chemistry' and 16 were not found in 'Elements of Chemistry'. 'Elements of Chemistry' has the broadest spread of learning task categories of the three texts. The increased proportion of level 1 tasks in 'Chemistry' and 'Elements of Chemistry' reflect the stated intentions in these texts of dropping the conceptual load and building student experiences up from basics.

The cognitive demand level of the evaluation items in 'Elements of Chemistry' cluster at levels 1 to 3, and are much lower than in the other two texts. In 'Experimental Foundations', level 3 dominates, stressing application, followed by level 4. For 'Chemistry', level 4 dominates, stressing conceptual knowledge, followed by level 1, with a significantly lower proportion at level 3 than either of the other two texts.

Student Questionnaires

A sample of students at each school was asked to complete a short questionnaire on the text they were currently using. Fifty students at one school were sampled for 'Elements of Chemistry' and sixty-three students at the other school were sampled for 'Experimental Foundations'. The results are presented in Table 4.

As can be seen from Table 4 only one major difference emerges, and that is that

'Elements of Chemistry' is given a much higher interest rating than 'Experimental Foundations'. It should be remembered, however, that differences between the two student populations could account for this response difference. Indeed, it is interesting to note the similarities between the ratings achieved by the two texts.

Question 1, relating to ease of reading, confirmed the results reported earlier, that 'Elements of Chemistry' is easier to read than 'Experimental Foundations'. Positive ratings (3.6 - 3.7 on the 5 point scale) are given to both laboratory exercises and illustrations in aiding understanding. Students also positively rate the comprehensiveness of both texts. However the worked examples in both texts were rated much lower (2.8 - 2.9). It would have been valuable to have ratings on this aspect for 'Chemistry' which appears to pay greater attention to the use of carefully developed problem-solving skills than the other two texts.

It is interesting to see the ratings given to end-of-chapter questions. Students rate them a good test of their understanding (3.8 - 4.1), yet also rate them as slightly towards the easy end of the spectrum (2.7 - 2.9).

DISCUSSIONS OF RESULTS

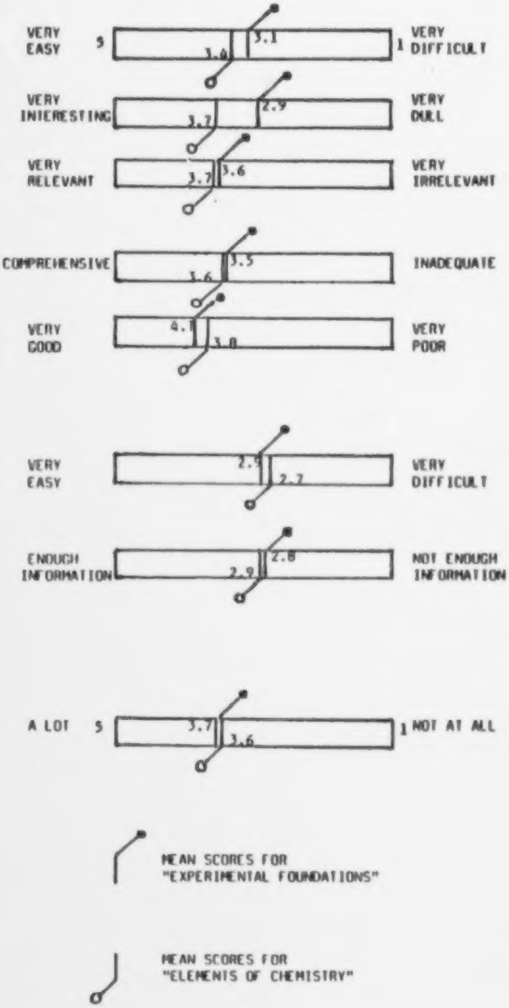
An analysis such as that described here provides a teacher with detailed insight into certain aspects of a text. It allows the teacher to predict likely advantages and disadvantages of incorporating the text into chemistry programs. It also alerts the teacher to areas where the teacher may have to redress imbalances or provide extra experiences. The analysis provided here is mainly descriptive, leaving it to teachers to make their own judgments about the importance of the revealed structures.

What is of much greater importance is the potential value of this type of analysis in the preparation and trialling of texts. There are clear structural problems, and potentially serious omissions and imbalances in each of the texts analysed here. The use by publishers and authors of such pre-publication analyses could do much to improve the standard of Chemistry texts.

The analysis reported here would be comfortably within the scope of most secondary school science departments to perform before choosing a text. In this respect, it is important to realise that such an analysis still leaves out a number of important features. For example, the careful sequencing of learning experiences, an impressive characteristic of 'Chemistry', is not revealed in this analysis. The whole area of attitudes has not been touched, and skills are only dealt with partly by the Cognitive Demand Scale.

Table 4: Responses to Student Questionnaires

1. Do you find that reading the text is:
2. How interesting is the text?
3. Do the laboratory exercises help you to understand the ideas presented in the text?
4. How do you rate the information in the text?
5. Are the questions at the end of the chapter a good test of your understanding of the chapter?
6. How easy/difficult are the questions at the end of the chapter to answer?
7. Do the worked examples in the chapters give you enough information/practice to enable you to answer the questions at the end of the chapter?
8. Do the illustrations increase your understanding of the chapter.



CONCLUSION

The analyses reported in this study provide detailed insights into three senior secondary Chemistry texts. They reveal significant weaknesses in all three texts. Science departments in schools are encouraged to perform such analyses before choosing texts. More importantly, publishers and authors should incorporate such analyses into the development and trialling of their texts.

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APPLICATION OF A CONCEPTUAL CONFLICT TEACHING STRATEGY TO ENHANCE STUDENT LEARNING OF ACIDS AND BASES

Brian M. Hand & David F. Treagust

INTRODUCTION

There are many studies (see for example, Gilbert & Watts, 1983; Mitchell & Gunstone, 1984) which show that students enter the classroom with preconceptions or misconceptions related to the science content to be learned. While the largest number of these studies is in physics, there is a considerable number of studies in chemistry and biology. Misconceptions in science may have been acquired through previous instruction (Bodner, 1986) or from experiences in students' daily lives (Head, 1982). One of the major problems facing science teachers is that students often leave the classroom without changing their misconceptions. Head (1982) and Pines and West (1986) point out that students may in fact hold two conflicting views at the same time, one being the correct one used at school, the other being the misconception which is used during everyday life.

If the actional view of a concept is adopted (Gilbert & Watts, 1983) in which a concept will change with experience, then a teacher can take a stance that misconceptions can be changed. Driver (1981), Posner, Strike, Hewson and Gertzog, (1982), Hewson and Hewson (1984), Driver and Oldham (1985), Pines and West (1986), and Minstrell (1984) have suggested strategies which encourage conceptual change from misconceptions to scientifically acceptable concepts Each of the strategies has five basic steps which involve the students in expressing their own ideas, providing experience with the students' prior knowledge, allowing time to conceptualize these experiences and use these concepts, and finally providing a supportive learning environment.

The strategy of conceptual conflict as used by Minstrell (1984) encompasses all these steps and is an example of the constructivist framework of teaching outlined by Driver (1981). For learning to be successful using this strategy, the major emphasis is placed on the interaction between the existing misconception and phenomena which can only be explained by the scientifically acceptable concept (Hewson & Hewson, 1984). Students are given the opportunity to discuss and rationalise any conflict in an attempt to encourage consideration and acceptance of the scientific explanation of the phenomena as their own (Pines & West, 1986).

In relation to student learning of acids and bases, no studies with early secondary school students were located. At the late secondary and first year tertiary level, Carr (1984) reported that only about a quarter of a sample of 24 New Zealand students fully understand ionic dissociation of acids. Also, Linke and Venz (1979) reported that non-science background first year university students have definite misconceptions in relation to the definitions of an acid and a base, with the interpretation of the pH scale, and were unable to relate the definitions of acids and bases to the pH scale. Cros, Maurin, Amouraux, Chastretle, Leber and Foyal (1986) described similar findings with first year university students in Italy who had trouble in correctly defining acids and bases, defining pH and using pH in everyday situations. From these findings it can be surmised that high school students would also have similar conceptual problems with acids and bases.

PURPOSE

The purpose of this paper is to (1) determine if high school students could overcome any documented misconceptions about acids and bases; (2) determine if a teaching strategy of conceptual conflict could successfully promote meaningful learning; (3) determine if retention of concepts can be achieved using a teaching strategy of conceptual conflict.

PROCEDURE

Sample

The sample comprised Year 10 students at a state high school in far north Queensland, where the school population has approximately 20% of students of Aboriginal descent. The students ranged from very poor achievers to above average achievement while their attitudes ranged from a desire to learn to no such desire. The latter group of students were filling in time at school and became an increasingly disruptive influence as the school year progressed. At the end of the first semester, the 78 Year 10 students in science classes were streamed on the basis of their overall score for first semester. Twenty three students who scored better than 55% overall for their first semester results were placed in one class. The major reasons for this streaming was to allow the more academic students the opportunity to work at a faster rate, to compete against each other for mental stimulation, and to work at a higher level of content difficulty. As a result of this streaming, the Year 10 science classes consisted of a more academically-inclined class, and three average to limited achievement classes. This situation existed when "Acids and Bases", a prescribed topic in the Queensland Year 10 science syllabus, was taught.

Pre-instruction interview

Before implementing the teaching strategy for conceptual conflict, any students' preconceptions or misconceptions about acids and bases were examined by individual student interviews conducted three months prior to the topic being taught. Five major preconceptions or misconceptions were identified and used as the student concept at the top of the worksheets. These misconceptions were: (1) An acid is something which eats material away or which can burn you; (2) Testing for acids can only be done by trying to eat something away; (3) Neutralisation is the breakdown of an acid or something changing from an acid; (4) The difference between a strong and a weak acid is that strong acids eat material away faster than a weak acid; and (5) A base is something which makes up an acid. Discussion with the local primary school principal indicated that many of these student ideas developed when students are exposed to the dangers of acids.

Development of Worksheets and a Teaching Strategy

Based on the result of the student interviews, seven worksheets were developed, each of which examined one concept, and was used to present the students with activities designed to create conceptual conflict. Each worksheet contained three sections, these being the student concept (that is, the usual occurring misconception), the practical component involving the conceptual conflict, and questions directly related to the practical component.

The student concept can be seen at the top of the worksheet in Figure 1. The rest of the worksheet consisted of an experiment(s) or activities for the students to complete, followed by a question related to the experiment(s) which the students were required to answer. Before each experiment was attempted, the students themselves decided on accepting or rejecting what was written down as the student concept. The authors believed it was important for the students to decide, so that they started each practical lesson anticipating what would happen. Consequently, students were able to make themselves aware of what they believed was going to happen during the experiment. Pines and Leith (1981) suggest that wherever possible students need to be aware of their misconceptions, prior to being confronted with activities which cannot be explained by their misconceptions.

WORKSHEET 1

Student concepts: Acids are something which eat material away.
Acids can burn you.

What is required of you is to test three solutions
Solution 1 is an acid
Solution 2 is a base
Solution 3 is hot water

- Remember they are 3 different solutions

Experiment 1: Place a small piece of metal, aluminium Al, in a test tube with approximately two and one half cm of solution.

	Observation
Solution 1 & Al	
Solution 2 & Al	
Solution 3 & Al	

Experiment 2: On a tile before you, place three pieces of material. Onto each piece of material, place two drops of the respective solution.

	Observation of Reaction
Solution 1 & material	
Solution 2 & material	
Solution 3 & material	

Question: Can hot water burn you?

Figure 1: Example of worksheet designed to engage students in conceptual conflict.

If the students had agreed to the student concept, there was a necessity to have practical activities which would show these concepts to be at odds with the students' observations. Each experiment or activity was designed so that the students were required to use a misconception in such a manner that the results obtained could not adequately be explained by its use. The degree of difficulty of each experiment varied. Some of the correct scientific concepts could be demonstrated quite easily, as seen in Figure 1 in which aluminium is "eaten away" by a base. Other concepts were not as simple, for example, in the detection of the process of neutralisation. Thus, all the worksheets were not of the same difficulty.

Questions were needed to extract from the experiments the particular inconsistencies that the authors wanted the students to confront. The question (or questions) appearing at the end of the worksheet was not linked directly to the student concept; rather the intention was to set the students thinking that maybe what they thought was correct was in fact not so correct. Questions were not asked on the worksheet which required the students to directly confront the student concept, since this was done during the small group discussion sessions. The more able students who finished quickly were keen to relate the inconsistencies pointed out by the questions to the student concept appearing at the top of the worksheet. When the small group discussion sessions were held, these students became much involved in what should be the correct concept.

A teaching strategy was developed around the propositions put forward by Driver (1986) and Minstrell (1984) which incorporated practical activities, small group discussion work, and whole class discussion work. To use these ideas effectively: the concepts were initially introduced by each teacher; a limited number of worksheets were required to cover all the practical activities involved in the unit; small group discussion was incorporated into the teaching plan; in addition, adequate time was needed to enable all students to examine the concepts by themselves. Subsequently, a 15 lesson teaching plan was developed which incorporated the use of the seven worksheets, time for student centred discussion and time for teacher directed lessons. Teacher directed lessons were necessary when concepts which the students had never experienced before were introduced. A sample of the lesson teaching plan is shown in Figure 2. The students were given two tests; one on completion of the unit and the other ten weeks after completion of the unit.

WEEK 1

Lesson 1
Introduction to the unit and an explanation of what we are trying to achieve.
Emphasis on students becoming involved with own learning.
Description of worksheet - point out student concept and how it was derived.
Emphasis on: Is the student concept correct?
Do the worksheet.
Acids and Bases require safety.
Homework - tasting of acids around the home, e.g., vinegar, lemon juice, yoghurt.

Lesson 2
Again, emphasis the setting out of worksheet.
Allow students to do worksheet.
Point out the need to observe carefully.
"Is the student concept correct?"

Lesson 3
Student will need their worksheets.
Put the student concepts in prominent place.
Students are placed in small discussion groups and asked to look at their results in relation to the student concepts.
"Are their concepts correct?"
"If you could change them how would you now describe them?"
Last half of the lesson needs to be teacher directed.
Real emphasis has to be placed on what the students concepts were, and what they are now.
Homework - collect petal samples.

Lesson 4
Do worksheet 3.

Lesson 5
Do worksheet 4.

Figure 2: Sample of lesson teaching plan designed to engage students in conceptual conflict.

RESULTS

The strategy of conceptual conflict was used to teach the unit of "Acids and Bases" in an attempt to change any student preconceptions or misconceptions to the scientifically acceptable concepts. At the completion of the unit all students received a class test consisting of a content section, which required recall of concepts learnt, and a process section, which required the application of the concepts learnt during the unit. An example of a content item is:

> When two acids of the same concentration are reacted with Magnesium, one reacts violently, whilst the other only very moderately. Why are the reactions different?

An example of a process item is:

> In an experiment in a laboratory you are given two beakers, one containing 20ml of 1M HC1. In the other you have some 1M NaOH.
>
> (a) How much NaOH would you need to add to the HC1 to produce a neutral solution?
>
> (b) Describe carefully how you would test for this neutral solution?

The results of tests for the three classes involved in the study are shown in Table 1. Two of the classes, class 1 and 2, contained students of average to below average ability in science, while class 3 contained students of above average ability in science. As can be seen from Table 1, class 3 achieved the highest marks for both content and process sections of the test. However, when scores from students with identified learning problems, as indicated by the student counsellor, are removed the two average to below classes have the same process marks as the above average class. This result would imply that these students are correctly applying concepts learnt during the unit.

At the completion of the semester, approximately 10 weeks after the initial testing, students were tested again. In this testing, only process questions were used due to the work programme followed at the school. The results of this testing, prsented in Table 2, showed that the two average to below average ability classes have fallen well below the score for class 3, the above average ability class.

TABLE 1

Results for the content and process sections of the "Acids and Bases" section of the end of topic test

	Complete Groups		Students with identified problems removed	
	Content Mean% (s.d.)	Process Mean% (s.d.)	Content Mean% (s.d.)	Process Mean% (s.d.)
Whole Group	62.1 (31.9)	45.1 (27.9)	-	-
Class 1 (n=18) Teacher - BH	53.3 (29.9)	39.7 (33.6)	65.6 (18.8)	50.4 (29.6)
Class 2 (n=19) Teacher - BM	43.0 (33.0)	41.8 (28.6)	63.0 (19.2)	55.6 (23.8)
Class 3 (n=23) Teacher - BH	84.3 (16.5)	52.0 (21.1)	-	-

Student interviews were also conducted immediately after and ten weeks upon completion of the unit. On each occasion, five students were interviewed, each representing one of the five grading levels used in the test. The authors attempted to reinterview students who had been interviewed prior to doing the unit. These individual, semi-structured interviews produced results similar to the class test results. However, misconceptions relating to neutralisation and the definition of strong and weak acids were not successfully changed to the scientifically acceptable concepts. Partial understanding was occurred for these misconceptions; there appeared to be insufficient conflict to cause a change to the students' belief system. Misconceptions relating to the definition of an acid, testing for an acid, and the definition of a base appeared to have been acquired as the scientifically acceptable concepts.

TABLE 2

The results of the process questions appearing in the end of semester for the whole group and individual classes.

	Complete classes		Classes with students removed	
	Mean %	(s.d.)	Mean %	(s.d.)
Whole Group	35.8	(30.6)	-	-
Class 1 (n=18) Teacher - BH	24.2	(25.8)	28.9	(26.0)
Class 2 (n=19) Teacher - BM	21.2	(20.6)	30.6	(19.8)
Class 3 (n=23) Teacher - BH	57.2	(29.6)	-	-

DISCUSSION

While the three classes had performed better on the topic and end of semester tests than had students in previous years, the conceptual conflict teaching strategy was not successful in causing conceptual change to all the misconceptions addressed in this study. Students who showed partial understanding of concepts on interviews ten weeks after completion of the unit appeared to have integrated some of the concepts into long term memory. Pines and West (1986) and Posner et. al. (1982) suggest that this situation of knowledge gain without full understanding is acceptable since students may have two concepts which conflict with each other for some period of time. Students will only change their misconception when the scientifically acceptable concept makes sense to them with enough experience of using the concepts in conflicting situations. These students have not fully accepted the new concept and at the same time have not rejected their own concept and would need to be provided with other examples of the misconception in a conflicting situation.

Approximately one third of the students did not change their misconceptions related to the definitions of acids and bases and, among other reasons, this may be explained by conceptual congruency. Pines and West (1986) suggest that if two concepts, one a misconception, are close to each other then conflict will not occur but rather there will be congruency of acceptance without change. The students knew that acids will react with metals and calcium carbonate but did not perceive these reactions as properties of an acid, rather they were just examples of an acid eating a metal away. Given this situation, there was no need for the students to change their own definition even though they readily quoted the reactions of acids with metals.

A major advantage of the teaching strategy for conceptual change in addition to conceptual growth was the definite improvement in attitude of the students. Further, students improved their observational skills, were much more self-disciplined and gained in self-confidence. Students no longer sat back and were not involved. Rather, students became active participants in their own learning with the result that they became "turned on" to science. In summary, the authors suggest that the teaching strategy of conceptual conflict appeared to have produced change in some students' concepts and ideas as well as a marked improvement in their attitude to science.

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ENHANCING TEACHING EXPERTISE : A CASE STUDY
OF THE PROCESS OF CHANGE

R. Ross, J. Hills, J. Baird, P.J. Fensham,
R.F. Gunstone & R.T. White

INTRODUCTION

This is an interim report of action research on the teaching and learning of science in a secondary school. It involves teachers at Eltham College, Melbourne, among whom are the first two authors, and academics from Monash University and the Melbourne College of Advanced Education. The article has three main sections: description of and comments on the method of research, an account of benefits that Bob Ross and John Hills perceive they have received from the project, and a report on the outcomes to date.

METHOD OF RESEARCH

Before the project began in early 1987 the members of the Science department at Eltham College were reasonably satisfied with their situation. Ross states:

> "We have a fairly well developed curriculum consisting of units of work which we have written; we have excellent laboratory facilities; all junior science classes take place in a lab; we do pretty well in the timetable battles, etc."

They did, however, recognise that there was room for improvement:

> (Ross) "Our curriculum had been in place for a number of years. Most of the units had been written three, four or five years ago and needed review. The students were not really jumping out of their skins with enthusiasm about Science. In fact, many were bored, especially at Year 10. However, we were unclear as to the nature of the problems. Moreover, we were not sure how to find out more about them or how we could overcome them. We were in a bit of a rut and not sure what to do next."

It is not clear whether the Eltham College teachers fulfilled the first requirement for conceptual change specified by Posner, Strike, Hewson and Gertzog (1982) of dissatisfaction with the present situation, but they were sufficiently open to new ideas to welcome the offer from Monash people to assist in researching improvement in the quality of teaching and learning.

It was arranged that the research would be a collaboration between five members of the Eltham College Science department and four Monash staff, of whom one (Baird, who is on secondment from Melbourne CAE) would have greater day-to-day involvement. It would be action research, with the teachers reflecting on their current practice followed by collaborative development of ideas; then action, based on those ideas; then evaluation of the action followed by further reflection. All of this would take place in a cyclic, ongoing way. What was wanted from the research was an infrastructure, a mechanism which could be used in a long-term way to continually evaluate and improve the teaching practice, the learning processes of the students, and the curriculum.

The first target for reflection was the way energy was taught, which was chosen because of its importance as a concept in science and because something about it is taught at all year levels, which gave the five teachers the opportunity to work together on a theme.

They began by considering how the topic of energy should be treated, drew up idealised concept maps, and met to discuss approaches. Baird interviewed them about their conceptions of energy. The discussions and interviews led the teachers to judge that there were flaws in their notions of energy, and that they were making little progress in seeing how to improve their teaching and the quality of the students' learning. Therefore they were ready to adopt a new approach.

A more direct course of investigation into the teaching process was then begun. Baird visited each of the teachers' classrooms over three consecutive lessons with the aim of comparing their teaching intentions with the actual outcomes. After each lesson the teacher and Baird conferred about how they thought the lesson went while students filled in questionnaires on their perception of the lesson. The teachers compared their perceptions with those revealed by the questionnaires.

> (Ross) "We were impressed in various ways with this exercise. We were forced to think very carefully about our intentions and aspirations for these lessons. Students clearly revealed their view of lesson outcomes. This exercise led us to realise the potential for improvement in our teaching."

An outcome of this exercise became the focus of the project. Because Baird saw lessons at all year levels, he was better placed than the teachers to compare the behaviours of the students. He noted a pronounced decrease in interest and enthusiasm of students as they passed on up through the school. Whereas Year 7 students were alert, enthusiastic and responsive, the older students seemed lethargic and uninterested. This observation was not a surprise to the teachers, for like teachers at other schools they had commented on it before.

To tackle the problem of what was responsible for students' loss of interest, the Eltham and Monash people began by having informal discussions and then took a half-day for a brain-storming session on the possible factors that may contribute to the drop-off. At this session the group identified 44 factors. It was obvious that not all could be investigated in detail and so the group selected just three of the areas for attention. Three sub-groups were formed, each selecting one factor for investigation.

Ross and Hills followed up the suggestion that students became less interested in Science because it held less challenge for them as they progressed through the school. They discussed what they understood by the term challenge in this context. The statement that they eventually used when talking to students was "a subject or topic or idea that is challenging is one that you have to think about, ask questions about or investigate further in order to understand it properly."

Ross and Hills composed a questionnaire which they administered to students at all Year levels 7 - 11. The questionnaire asked students to:

(a) compare the amount of challenge in Science compared with other subjects;

(b) compare the amount of challenge in difference Science topics; and

(c) explain what they found challenging in the different topics and in Science generally.

Responses were, of course, varied, but the things that students found challenging could be divided into two broad groups - those that were challenging in a positive way, e.g., new ideas, different work, practical exercises - and those that were challenging in a negative way, e.g., work that was not well explained by the teacher, or excessive factual content.

The questionnaire was followed with student interviews in order to probe more deeply into their responses, and to elicit more detail on their feelings. Ross and Hills met with a randomly selected group of students from Years 8 to 10. The meeting was recorded on video.

> (Ross) "Students were very open in their responses to our questions, and the discussion ranged freely and fairly widely. Although the purpose of our investigation was the consideration of factors affecting challenge, at this stage the boundaries of our line of research started to become a bit blurred. We were drawn more and more (by student responses) into aspects of science they found interesting, as well as challenging. This led us into areas of investigation which overlapped significantly with those of other groups."

Factors that students suggested were responsible for fall in interest in science included lack of relevance of the knowledge to their lives, triviality and repetitious nature of practial exercises, the quality of the teaching, and the lack of time to understand a topic before moving on.

All of the findings were considered in an attempt to develop a more satisfactory teaching program for a unit on Force that had rated poorly with year 8 students. Ross and Hills interviewed Year 9 students who had done the unit the previous year, and collected the following comments:

- much of the work was irrelevant and academic. The section that dealt with whiplash ("inertia") was one of the few that was interesting to them;
- experiments were trivial and repetitive. They had to use the "force measurers" in too many simplistic activities;
- some said that they did not do well in the unit because they did not feel moved to try and this was because they were not challenged;
- they did not like the A.S.E.P. books - they found them boring.

The students suggested that to improve the unit, and the science course as a whole, the teachers should:

- cut down on the amount of time spent in reviewing the results of the activities;
- have options;
- give students the opportunity to design and carry out their own practical activities;
- have mid-unit tests which will give students the chance to assess their own progress.

The students' reactions were discussed by the whole research group. Although there was useful clarification of our own ideas of force, little progress was made on how to teach it in a way which students would see as relevant to their experience and daily lives.

PERSONAL BENEFITS

> (Bob Ross) "The project has helped me in establishing a way of identifying problems, and methods of handling them. This is a benefit that will always be useful to me. I feel more in control of our situation now than I did previously. I certainly don't know the answers to all of our difficulties but I feel that I can analyse them more closely and carefully, and work with them. This is better than a vague notion that all is not well, but being not very sure what it is or where to start in trying to handle it.
>
> Secondly, the expansion of a dialogue with staff has been most beneficial. As a Head of Department, I have always been reluctant to require staff to discuss issues other than the immediate administrative necessities, as they all work hard and value their spare time in school. So it has been gratifying to see the blossoming of a desire and willingness to discuss the teaching and learning process itself; to try new techniques; to encourage others; and to share in the obvious successes of the project.
>
> I have also enjoyed enormously the opening of a dialogue with students in the school. The consultations and interviews have yielded lots of information but have also been fun. I now regularly consult my classes on their feelings about a unit of work; what should be changed; what has been successful. They are more forthcoming each time and seem to value the opportunity to make their contributions to the program.
>
> And, last but not least, the opportunity to work with someone from outside our department has been of inestimable benefit to us all. The provision of expertise, detached views, and encouragement have been the driving force for the project."

(John Hills) "In general, I would classify myself as a teacher who works reasonably hard but does not go looking for extra work. In some ways, I am a perfectionist and have therefore often felt that there is not enough time in a day to do the job properly. If time was short, the first thing that suffered was preparation. This made teaching less satisfying.

I have also considered most educational research hard to relate to, too general and seemingly too large a task to tackle, given the time pressures mentioned above. Early in my teaching career, I taught students with the overall aim of them learning work so they could hopefully pass a test. During that time, I spent much effort trying to protect students from failure by spoon feeding them. As years passed, I noted that several students who left school to tackle university courses were failing and dropping out in their first year. My unsubstantiated conclusion was that the spoon feeding was responsible for this. I then assumed that self discipline was a necessary quality for students to develop and that by letting students experience failure they would have to develop self-discipline to survive. This change was essentially the extent of my educational research, if you can call it that, in nine years of teaching.

As you would expect when John Baird came to the school and invited me to join the project, I was quite negative. In fact, I joined the team because most other members of the department had agreed to and I felt like I would be letting the side down if I did not do so. Again my lack of enthusiasm was due to a further time commitment which I did not need and also the fear that the research would involve talking in generalities, never really achieving anything. Initially, John was seen as the man who aggravated your conscience if you had not completed the weekly task set. As time passed, I gradually became positive towards what we were doing, although I don't know what factor made me turn the corner. Time is still a pressure but in hindsight we have rarely spent more than two hours in any one week on this project and there have been several weeks where we have done nothing - though I guess we are now informally reflecting on our practice without consciously doing so. By aiming for small short term goals the research seems less of an inconvenience and more natural inquiry into what, why and how well I am teaching, which must overall lead to increased job satisfaction if improvements are made."

OUTCOMES TO DATE

Action research pervades the whole of one's involvement, and is not restricted in its effects to one or two outcomes. Further, it takes a long time for its effects to become clear. Hence this is an interim report that picks out changes in practice that the research has promoted. There are not yet any extensive data to report on changes in perceptions and behaviour of students.

The first instance of how the reflection and discussion promoted by the project led to a change in practice occurred late in 1987. During a school inservice day the science department considered the problem of making the Year 10 science course more appropriate, given that students of mixed ability and motivation levels were currently taught the same material. By pitching at the middle ability range, we did not challenge many of the more able members of the group. By so doing, we also created a problem where many students found the transition from Year 10 to Year 11 science-based subjects a large jump for which they were not prepared.

The discussion led to two possible strategies being discussed:

i. the introduction of streaming, whereby one group of units of higher conceptual difficulty and volume of work would be developed for the group of students intending to pursue science in Year 11.

ii. the writing of synopses of possible new units as well as current units and give students the choice of which units they would prefer to tackle. The units which were deemed as being of a higher conceptual difficulty were stated within the synopsis as suitable for gaining a good basis for the appropriate Year 11 subject (i.e. Biology, Chemistry, Physics).

The group unanimously preferred the second alternative, because it might lead students to stream themselves as well as allowing them to pursue individual interests. This preference probably indicates a change in view about practice.

To implement the second alternative, a program was devised in which the 112 students were allowed to choose between five groups which followed different patterns of choices of eight units from a total offering of 14. Although formal evaluation of this system has not yet been made, students have commented positively about it. Its merits have spread to lower forms, where students have asked that it be introduced for them, too.

Another change in practice has concerned assessment. Our surveys have indicated that students wish to become more involved in developing their assessment programs. In the past, assessment in Junior Science has been fully teacher determined and has relied essentially on test performances alone as a means of determining a student's grading, although assignment work and general written work have been given some consideration.

One change that followed analysis and discussion of the survey data was to give students the opportunity to determine the criteria for assessment. This has produced more varied methods.

Bev Walsh used the following methods to assess performance in Year 10:

- open book testing
- assignment work (one unit was assessed solely on this basis)
- notebook work
- class work.

These changes led to previously highly graded students now needing to work consistently in class in order to achieve the same grade.

John Hills meanwhile worked on increasing the level of self assessment by the Year 8 science students. Initially they were asked to assess their practical work based on:

i. their skill, involvement and efficiency in carrying out the exercise; and

ii. how well they understood the exercise prior to class discussion. As students began to accept this process, self-assessment spread to the grading of their unit booklets and eventually to the students determining what factors were to be assessed and the percentage breakdown allocated to these factors. For example, in the latest unit, the following categories and weightings were decided upon:

i Completedness 20%
ii Presentation 30%
iii Depth of understanding 15%
iv Practical work 15%
v Overall effort 20%

In general, students have been enthusiastic towards grading themselves, but a meaningful scale for measurement of their achievement has yet to be reached. However this will occur soon through further reflection and trials.

Possibly the greatest change in practice, and one which we are documenting for a subsequent report, is the dramatic increase in discussion between teachers and students. This involvement of students in overt reflection on the purposes of the science program and on how best they might be achieved is the mainspring of the project. In retrospect, what seems remarkable was the negligible level of that interchange that existed before the action research began.

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PRESERVICE PRIMARY TEACHER EDUCATION IN NSW : A COMPARATIVE ANALYSIS OF ESPOUSED SCIENCE EDUCATION CURRICULA

Keith Skamp

INTRODUCTION

Recently the "Green Paper" (Dawkins, 1987, p. 18) commented that a "better understanding of ... science by primary teachers" is needed, and it was proposed that a major discipline assessment of "teacher education in ... science" be undertaken. These remarks beg the question: "What do we know about the science education courses provided in preservice primary teacher education programmes? Two recent reviews of science teacher education (Owen et. al. 1983; Tisher, 1986) concluded that there was little written about preservice primary teacher education courses.

Following the above review by Owen et. al. (1983), a major project in science in primary teacher education was conducted (Owen et. al. 1985). One aspect of this work surveyed the content and structure of preservice primary science courses in Victorian CAE's. This paper extends the data available on preservice primary science teacher education courses by analysing and comparing the espoused curricula of primary science curriculum units offered by eleven NSW tertiary institutions in 1985/7. Comparisons are made with the Victorian study.

PROCEDURE

Advanced education institutions in NSW are required to produce documents for accreditation and review purposes. These documents include such information as the rationale, structure and organisation of programmes and, if appropriate, review procedures. Detailed descriptions for all units included in particular programmes are included. During the period 1985/7 Bachelor of Education (Primary) [B.Ed.] programmes in all institutions were reviewed. MacLeod and Rankin (1987) describe in detail the nature of the review process and the structure of the B.Ed. This article compares and analyses the written descriptions of the compulsory science units preservice teachers must complete to obtain the minimum qualification for teaching in NSW (a 3 year Diploma of Teaching).

TABLE 1
PRESERVICE PRIMARY SCIENCE EDUCATION COURSES

Number, Length and Semester Level of Units

CAMPUS	NO. OF UNITS	SEMESTER LEVEL	LENGTH (Contact Hours)	TOTAL LENGTH (Percentage of Dip.Teach Programme)		SEMESTER HOURS[1]
A	2[2]	2	65			
		4[2]	35	100	(6.3)	7.7
B	1	1 and 2	52	52	(3.3)	4
C	2	2	36			
		3	36	72	(4.6)	6
D	2[4]	1	13[5]			
		6	18	31[3]	(2.0)	2.4
E	1[2]	3	39			
		(6[2]	13)	52	(4.2)	4.3
F	2	4	24			
		5	24	48	(3.5)	4
G	2	1	26[5]			
		4	39[5]	65	(4.5)	5
H	1[4]	3	26	26	(2.1)	2
I	3	1 or 2	20			
		3 or 4	20			
		4 or 5	20	60	(3.8)	4.6
J	2	2	26			
		4	26	52	(3.7)	4
K	2	1	30			
		4	30	60	(4.2)	5

NOTES:

1. A semester hour is defined as one hour contact time for each week of the semester.
2. A second unit in a later semester on environmental education incorporates mainly science and social studies curriculum strands. The science component is approximately 35 contact hours (but also includes part of a 5 day field camp) (Campus A) and 13 contact hours (Campus E).
3. Two interdisciplinary field studies (for one week) are also involved.
4. These units are shared with other curriculum areas and it is assumed that there is an equal distribution of contact hours.
5. Based on the assumption of a 13 week semester which has not been verified.

The results are presented in two forms: institutional profiles relating to different course characteristics and overall summary data. A broad picture of preservice primary science education in NSW is therefore obtained as well as descriptions of individual campuses.

For the purposes of later discussion three terms need to be clarified. "Programmes" refer to the overall Dip. Teach. structure; 'units' refer to subjects taught in a semester, and 'courses' include all the units which make up a subject, here primary science curriculum studies within a programme.

OVERALL ANALYSIS AND PATTERNS

Length and Level of Courses

In all but one institution (see Note 2, Table 1) the course consists of two units (or its equivalent) offered in separate semesters. Contact hours show considerable variation between Colleges with a mean of 50.7 hours, and a range of 74 (26 to 100). [The mean semester hours was 4.45 with a range of 5.7 (2 to 7.7) - this compares with the Victorian CAE (VCAE) mean of 5 with a range of 5 (3 to 8) (Owen et. at. 1985)]. As a fraction of the total preservice programme compulsory primary science curriculum units comprise between 2.0 and 6.3 percent (mean 3.9) [VCAE : 2.7 to 8.3 percent; mean 4.7]. On average compulsory science curriculum units account for approximately seven (7) percent of "curriculum studies" units as defined by MacLeod and Rankin (1987, p. 6). [They determine that the average preservice teacher education programme in the eleven higher education institutions studied included 56.7 percent 'curriculum studies']. Other preliminary analyses suggest that science and music share approximately the same proportion of teacher education programme time, behind English, mathematics, and social science but ahead of art, craft, physical education, health, drama and dance (NSW Department of Education curriculum areas, specified by syllabus documents). Full details of the number, semester level, length and percentage of programme of the primary science curriculum units is provided in Table 1.

Organisation of Courses

Eight of the Colleges (A, B, C, E, F, G, I and J) offer science as a separate curriculum study course. Of these, two Colleges (A and E) offer only one science curriculum studies unit but environmental education is the substance of separate units in which science education contributes approximately fifty (50) percent. Another institution (H) involves a unit in which science and social studies education is taught in the same unit, while campus F, although not offering shared units, states that the science curriculum studies units were designed to link with the social studies curriculum units. Two institutions (D,H) offer units in which science and health education share the unit (science shares the unit with social studies and health at campus H), while one College's (K) science curriculum units are shared with visual arts.

In those seven Colleges where there are two science curriculum units (apart from the one case where the two units form a year long course), the semester separation varies from one to six. For all of these courses the second unit explicity states that the first is a prerequisite for its study. Only two Colleges set prerequisites for their first science curriculum unit; one (E) requires a general teaching unit Introduction to Teaching; the other (H) (as it is offered in second year) requires a defined number of credit points at first year level.

Course Conceptual Structures

Eight of the Colleges structure their units around pedagogical and curriculum concepts as they relate to primary science education. Two institutions (A, C) (and possibly a third, I) include at least one unit which stresses an understanding of science and science concepts per se (albeit with primary science classroom applications added). Of these College C's second unit's objectives and content clearly indicate that it is science concepts that guide the unit's planning - not science education concepts.

COURSE OBJECTIVES AND CONTENT

As the programme reaccreditation requirements ask for the unit outlines to be written in an "objectives" model format, the listed content/topics for each unit were aligned with the most appropriate unit objective(s) in order to determine categories of objectives/content. Although there is similarity between some of the categories, e.g. 'teaching using inquiry procedures' and 'science process skills' each category appeared sufficiently distinctive for it to remain separate. To illustrate the nature of the 18 categories that eventuated (see Table 2) and the extent of the interpretation involved, the following shows one of the most and least specific objective(s)/content 'pairs' for an identified category.

Nature of science	
Develop an understanding of the nature of scientific inquiry, and how this leads to interpretations of natural phenomena.(C)	Methods of science, the nature of laws, theories and hypotheses, the contribution of Mill, Popper, Kuhn, Lakatos and Feyerabend (brief outline only): Objectives of science education in terms of skills, knowledge and understanding, attitudes, values and feelings; Limitations of science.(C)
Be familiar with the nature of science and its use of a problem solving discipline.(I)	Processes of scientific inquiry.(I)

It needs to be emphasised that the decision as to whether a College's course included certain objectives/content in a particular category is entirely dependent on whether the stated objectives/content in the accreditation documents referred directly to same. Even with this restriction the interpretation placed on the objectives/content listed is considered to be quite liberal.

TEACHING AND ASSESSMENT PROCEDURES USED

The development of institutional profiles for 'teaching procedures' (similar to Tables 1 and 2) indicates that a practical laboratory/workshop approach to teaching science curriculum studies predominates. These practical sessions primarily involved students in inquiry oriented investigations which could have application in the K-6 classroom. The focus did vary. Some units stressed an understanding of primary science concepts; others the nature of science (especially process skill use); and in at least one instance the application and evaluation of curriculum resource material. These procedures are usually supplemented by tutorials and lectures and in seven instances by field work and/or excursions, with one course visiting a field study centre. Three campuses require their students to be involved in in-school science experiences, and a further two use demonstration science lessons. Only one campus made reference to microteaching, and another to use of computers. The picture appears similar to Victorian CAE'S (cf. Owen et. al., 1985, p. 6-13).

An analysis of assessment procedures indicates that the emphasis is obviously on records of practical/workshop exercises/projects (7 campuses) and preparation of lesson plans, teaching materials and units or programmes (7). In ten courses such procedures are supplemented by tests and/or examinations.

OVERVIEW OF COURSES

Pen pictures of each course highlighting their key and unusual features have been prepared (see Note 1). However, the organisation, objectives/content and methodology of all the courses can be partially discerned by combining data in Tables 1 and 2 and reference to the text. Although there are some distinguishing features between the courses the overall impression is one of similarity. In summary, the following is considered to be noteworthy about particular courses; a unit focus on the nature of science (science processes, SCIS concepts [see Carin & Sund, 1985, p. 177ff]) and STS interactions (campus A); discrete EE units (to which science was a main contributor) (A and E); a unit focus on science concepts/topics (C); the use of microteaching and computers as a teaching procedure and the former also as an assessment procedure (F); the organisation of the science curriculum units around the theme People as Part of a Biophysical System with unit subthemes of Diversity, Interaction and Change (I). Other special characteristics of courses may be present but these features stood out as being different from the available written unit outline descriptions.

DISCUSSION OF THE ANALYSES

Length of Courses

Considerable variation occurs in the time allocated (actual and proportionate) to science curriculum units between campuses. This probably influences the emphasis future teachers perceive their courses place on certain school subjects and may have flow-on effects in their actual teaching. Owen et. al. (1985, p. 2-16) report that recent College graduates perceived that less emphasis was placed by their science preservice course on a profile of identical teaching knowledge, skills, and attitudes (e.g. an ability to evaluate student progress) compared to their mathematics course. Time involved in the respective preservice courses was hypothesised as a likely explanation.

Boylan & Hill (1986, p. 79) in a study which found 58% of the preservice primary teachers about to enter teaching were concrete thinkers on a volume conservation task argued that such a result was not surprising due to the "small science component in (preservice) courses". One future research study would be to determine if the amount of time devoted to science in preservice education influences future teachers' confidence to teach primary science.

Conceptual Organisation of Courses

All compulsory NSW (and most VCAE) courses had a curriculum studies rather than a personal development emphasis. Australian studies (Ginns & Foster, 1978; Dooley & Lucas, 1981) tend to suggest that 'science content' courses (personal development) do not change preservice students' attitudes towards science or primary science teaching, but 'curriculum studies' courses do positively affect changes in attidues towards teaching primary science (but not science). American studies have usually found similar results (e.g. Lawrenz & Cohen, 1985, and references cited within). Even though NSW courses almost invariably fit the curriculum studies mold the type of science units to be offered to preservice primary teachers should not be considered clear cut. For example, although Walsh et. al. (1984) and Walsh & Lynch (1985) reported difficulties with first year primary science teacher education students doing a compulsory content based science unit (similar in difficulty to a Faculty of Science unit) they did note it had the effect of encouraging relatively more to choose second year science electives. Further, of those that went on to the second year elective, 82% commented in interviews that the first year unit had a positive effect on their attitudes to science. More studies are needed to further substantiate the almost complete acceptance of the curriculum studies approach and to determine where (if any) the balance should lie. This is especially so as 98% of American tertiary institutions (responding to a survey, n=45), required their elementary teachers to do science content courses (Mechling et. al., 1982), and the National Science Teachers Association (USA) [1987, p. 2] recommends a 'minimum of twelve semester hours of laboratory or field-oriented science including course work in the biological, physical and earth sciences'. Studies such as Dobey and Shaffer's (1984) suggest the amount of knowlege preservice primary teachers have may influence the degree to which they exhibit science inquiry teaching behabiour.

TABLE 2
OBJECTIVES & RELATED CONTENT
INSTITUTIONAL PROFILES[1]

CAMPUS OBJECTIVES/ CONTENT	A	B	C	D	E	F	G	H	I	J	K	NUMBER OF CAMPUSES REFERRING TO 'AREA' (Maximum = 11)
Resources for K-6 science teaching	2	1	1	1	1		1,2	1	2	2	1,2	10
Science skills (especially process skills)	1,2	1	2	1,2	1		1,2	1	1,2	1	1	10
Primary science concepts/topics	1,2	1	1,2	1,2	1	2	1 ?		1,2	1,2	2	9 (10)[2]
Environmental Education	2	1		2	(2)[3]		2	1	2,3	1	1,2	9
Evaluation	2		1	1	1	1	2		2	1	2	9
Selection & design of learning activities		1 ?	1	1,2	1 ?	1	2	1	2	1,2	1,2	8 (10)
N.S.W. Investigating Science (K-6) Syllabus	2	1	1	1		1			1	1	1	8
Teaching for attitude development				1	1	1	1	1		1	2	7
Concept development: teaching strategies and/or background		1		2	1		1		1,2		1,2	6
Teaching using inquiry procedures	1,2	1				1			1	1,2	1,2	6
Integrated/ interdisciplinary approaches	2		1			2	1,2	1				5
Programming	2			2		2		1				4
Attitude toward science and science teaching					1	1			1	1		4
Nature of science	1		2	2 ?					1			3 (4)[2]
Role of Science in K-6			1		1		2 ?					3 (4)
K-6 school based science planning						2	2				2	3
Using equipment/ developing practical techniques			1		1		2					3
Science-technology-society interactions	1											1

NOTES:
1. Numbers in columns beneath campuses refer to the unit in which the 'area' is covered, i.e. first, second or third.
2. Numbers in parentheses reflect the uncertainty of assigning the 'area' in some cases.
3. Campus M offered a separate unit entitled Environmental Education.

Objectives and Content of the Courses

Overall Course Emphasis

Three approaches to primary science education can be identified (MSU, 1987, p. A10): Science as inquiry (which emphasises the structure of the discipline and the nature of scientific inquiry); the science - technology - society approach [S-T-S] (aimed at helping children "to become scientifically literature citizens who can understand and deal with increasingly complex science-related social issues, rapid changes in technology, & continual changes in science"): and 'conceptual change teaching' (which advocates challenging children's misconceptions). From Table 2 and the pen-pictures it would appear that NSW courses emphasise science as inquiry, but not with an overt stress on the conceptual structure of science (with perhaps two or three courses being exceptions). To some extent the S-T-S approach is also present due mainly to the EE component in most courses, although only one course specifically mentions S-T-S interactions. Typical EE topics however hint at same. The 'conceptual change teaching' is not present in ten of the course descriptions with only one College making reference to the "preconception /children's ideas" research.

Specific Objectives/Content

Comparisons of the objectives/content of the courses with the criteria suggested by Pratt (in Harms & Yager, 1981, p. 77), in "Project Synthesis", and the "responsibilities of the (primary science) teacher" cited by the NSW Department of Education (1980, pp. 18-19) suggests that the following areas may be underemphasised: (i) the role that primary science can play in the physical and moral development of children; (ii) documentation of class programmes; (iii) contribution to school level science curriculum development; and (iv) the safety of pupils (only one College specifically referring to the last-mentioned). It is also worth noting that 'the use of computers' and 'gender and science' were referred to by only one institution in each instance.

Without more detailed investigation it is difficult to further interpret the objectives/content statements. A graduate survey similar to that used in Victorian CAE's would provide useful data and the results reported in Table 2 could be superficially compared with those of Owen et. at. (1985, p. 2-16).

Course Pedagogy

Joyce and Showers' (1977) review of research on the acquisition of teaching skills and the transfer of learning concluded seven training components are positively related to the development of teaching skills in preservice teachers. The components are (a) presentation of theory; (b) modelling or demonstration; (c) practice under simulated conditions; (d) structured feedback; (e) forecasting the transfer process; (f) developing "executive control"; and (g) coaching for application. [Full details are given in Owen et. al. (1985), Chapter 3.1)]. Comparison with institutional profiles of teaching procedures and other unit outline information suggests (a) is adequately covered. Component (b) probably received indirect attention by the use of the practical workshops by most courses in which students are involved in activities similar to those they would use in classrooms, but direct use of live or simulated (e.g. video) demonstrations of teaching skills/approaches with children has not been highlighted by a majority of Colleges. Components (c) and (d) may be included in five of the courses, but (d) seems most unlikely [see Owen et. al. (1985, p.-7)]. "Forecasting" (e) cannot be gauged from the data available, but "executive control" (e.g. ways to adapt content, teaching skills etc. to different grades, classrooms etc.) received attention in various ways. These included: (i) reference to developmental levels in children's science abilities and the inclusion of interdisciplinary/integrated approaches - see Table 2; (ii) requiring lesson note, unit or programme preparation for assessment purposes which would need consideration of ability levels of children, e.g. one institution specifically stated that a programme segment was to be prepared for an infants class; (iii) the organisation of College courses which used similar procedures, content etc. across curriculum areas e.g. units which combined curriculum areas such as science and social studies because they both advocated inquiry approaches to teaching and learning. Most institutions relied on Practicum for "coaching for application" (g) to occur-however real doubts about the effectiveness of this situation for science education have been expresssed elsewhere (Owen et. al., 1985, p. 3-17).

In summary it seems that overall the teaching/learning and assessment procedures described in the documents do not provide sufficient evidence of components (b), (c), (d) and (g) being present or occurring on a regular basis. Two worthwhile studies would be to (i) investigate whether there are barriers to implementation of these steps and if they can be removed and (ii) find out if students exposed to courses with greater emphasis on the various steps feel more confident about their science teaching ability.

CONCLUSION

Compulsory preservice primary science education courses in NSW without exception employ a curriculum studies approach (with only one unit planned around science concepts per se). The overall emphasis of the courses is predominantly a 'science-as-inquiry' variation (with some STS - environmental education - 'overtones'). Specific objectives/ content of the units is markedly similar with some minor variations. The teaching-learning procedures are basically practical workshop approaches. Only a small number of Colleges involve students in most of the key skill development and transfer steps. Assessment procedures mainly are exams and records of practical/workshop exercises, with a significant number of Colleges requiring unit or programme preparation - assessment which involved student demonstration of science teaching skills was minimal although written descriptions may have been required.

The National Science Teachers Association of America (Mechling et. al., 1982) recommended that "science methods courses" should (i) survey a variety of topics and programmes, (ii) provide ample hands-on activities and experiments appropriate for elementary school children, (iii) concentrate on the development of basis science concepts, accompanied by appropriate activities to illustrate same, (iv) provide more science activities and lessons geared to primary grades, and (v) provide class instruction in the step-by-step development of a typical science lesson at various grade levels. An example of a course description claiming to fulfil these requirements is given by Engels (1985). NSW courses would seem to adequately satisfy (i), (ii) and (iv) but as discussed earlier (iii) and (v) are treated to different degrees by the various courses [especially if (v) is interpreted in terms of skill development and transfer].

This paper has described the NSW situation as it existed in 1985-7. The analysis it is hoped will encourage science teacher educators to reflect on their own courses with at least some knowledge of what is occurring elsewhere and whether such courses are meeting broadly stated (or implied) criteria.

Notes

The following may be obtained from the author: a complete listing of objectives/content pairs for the eighteen areas; pen pictures for each College's science education courses; a fuller description of the objectives/content of the courses and associated discussion of same; further details of teaching and assessment procedures and resources used, as well as institutional profiles.

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CLASSROOM DIALOGUE AND SCIENCE ACHIEVEMENT

John Clarke

INTRODUCTION

CONTENT AND STRUCTURE IN CLASSROOM DIALOGUE

The idea that the "...structure of classroom verbal communication is a fundamental variable in the understanding of the teaching process" (Anderson; 1974: 219) is supported by the proponents of inductive (e.g. Bruner; 1966), deductive (e.g. Ausubel; 1963) or eclectic approaches to teaching (e.g. Cazden; 1986). Analyses of classroom language have devoted little attention to the structure of knowledge communicated, the focus being more on the frequency and periodic occurrence of pedagogical moves (Galton, 1978; Simon and Boyer, 1975). Two significant exceptions are the work of Peel and Anderson. Peel's methodology of "describer" and "explainer" categories (Peel; 1975) although considered to have "...considerable potential (is)...only (at) a beginning and there is scope for further research" (Michell and Peel; 1977: 264). Anderson's "kinetic structure theory" (Anderson, 1971) although sophisticated and widely used, focusses only on teacher talk.

A technique that not only analyses the dialogue at a level of sophistication similar to kinetic structure theory but also incorporates the student contribution to the dialogue, is the Thematic and Structural Analysis (TSA) Technique (Carss; 1973). Further, since the co-occurrence of words is a fundamental aspect of the analysis, the context of the words rather than just their frequency of occurrence is accounted for.

THE THEMATIC AND STRUCTURAL ANALYSIS (TSA) TECHNIQUE

The TSA Technique was originally developed as a methodology to provide a sophisticated analysis of text material (Carss, 1973; Clarke, 1973). It has recently been modified to analyse dialogue using Bellack cycles (Clarke, 1987a, 1987b; Clarke and Carss, 1988). The procedure produces a set of themes (co-occurring word clusters), the structural relationship amongst the themes ("essential structure") and the temporal structural relationship amongst the themes across the Bellack cycles of the dialogue.

Before the original dialogue can be analysed, it is "reconstructed" using techniques devised by Loflin, Guyette, Barron and Marlin (1972) to make all of the implied language explicit.

AN EXAMPLE OF DIALOGUE ANALYSIS

The dialogue from three sequential lessons is analysed here (Note 1). The dialogue was divided into 123 Bellack cycles. From the original corpus of words, 31 words with frequency of occurrence >15 were selected for further analysis. These remaining words and their frequency of occurrence (F) are shown in Table 1.

Word	F	Word	F	Word	F
answer(n)	61	hair	15	SR	71
answer(v)	36	human	26	student	279
blue-tongue	21	lizard	18	teacher	95
body	15	marsupial	47	temperature	95
cage	22	mean	20	TQ	94
characteristic	48	mouse(adj)	21	TR	75
container	17	mouse(n)	123	type	31
correct	50	primitive	17	up	15
dog-fight	15	put	27	way	15
go	16	question	46	warmblooded	23
				you	208

Table 1 Word Frequencies for Class 2 Dialogue

The principal components analysis identified 9 interpretable principal components (themes) which accounted for 73.8% of the variance. These themes are shown in Table 2.

Theme	% Var	Words in Theme(Loadings)
1. Teacher-student question-answer interaction	15.1	answer(n)(.84) SR(.79) answer(v)(.84) TR(.74) question(.82) TQ(.65) correct(.77)
2. Characteristics of mammals - 1	11.3	body(.87) human(.86) go(.86) up(.72) temperature(.77)
3. Activity: mice fighting	10.6	put(.88) fight(v)(.72) mouse(n)(.77) way(.65) container(.77)
4. Example of a cold-blooded animal	6.8	lizard(.98) blue-tongue(.97)
5. The meaning of warm-blooded	6.8	mean(.90) warm-blooded(.89)
6. Apparatus for housing the mice	6.5	mouse(adj)(.90) cage(.87)
7. Characteristics of mammals - 2	6.5	hair(.92) characteristic(.90)
8. Type of mammal	5.9	primitive(.92) type(.89) marsupial(.47)
9. Reference to student	5.7	you(.92) student(.92)

Table 2 A Summary of Themes in Class 2 Dialogue

All themes can be named by inspection although one of them needs confirmation from the transcripts. They confirm that Theme 2 is about the warm-blooded characteristic of mammals. The overall structure of the dialogue is shown in Figure 1 and its "essential" structure is shown in Figure 2. Significant cross correlations of the themes are also shown in Figure 2.

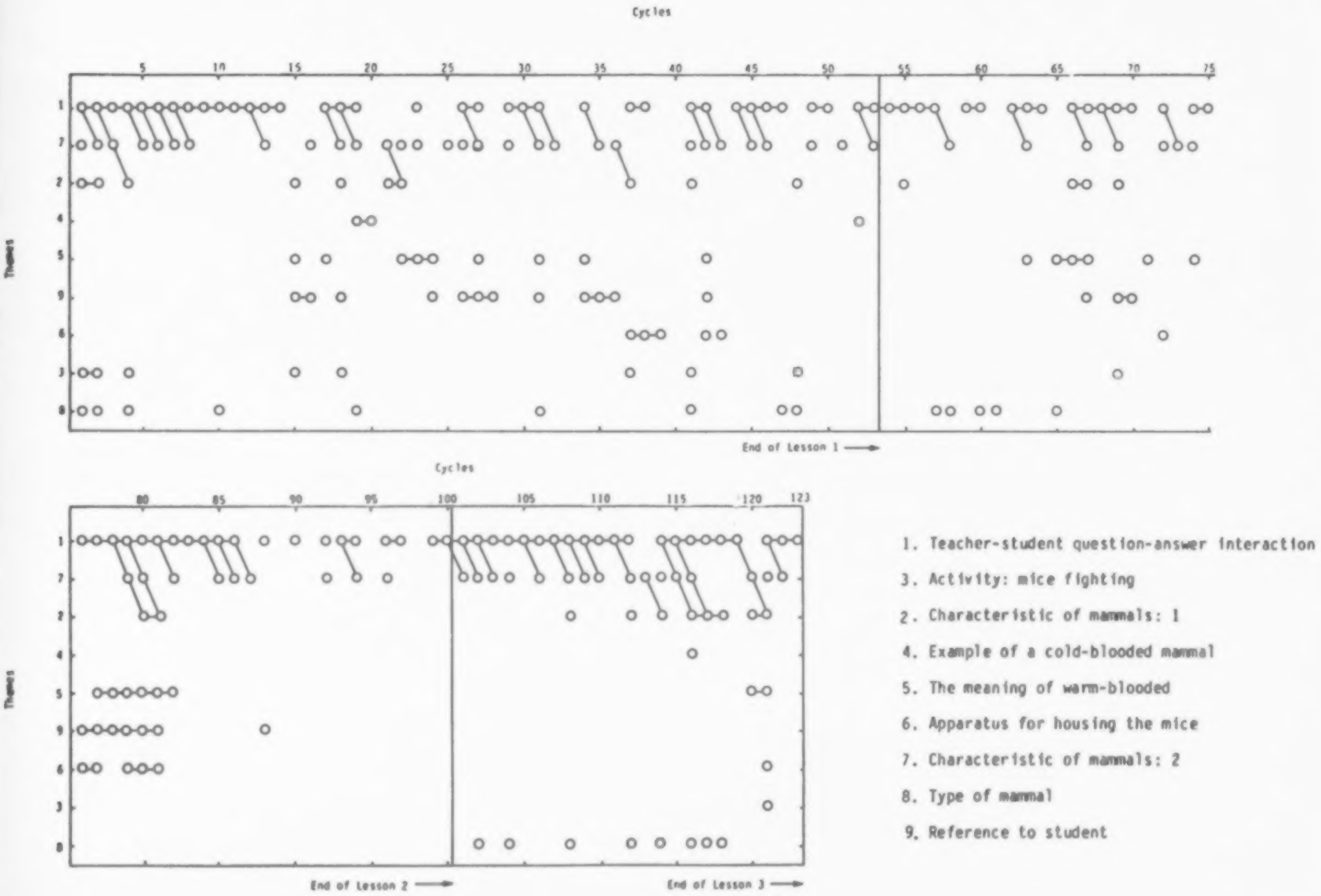
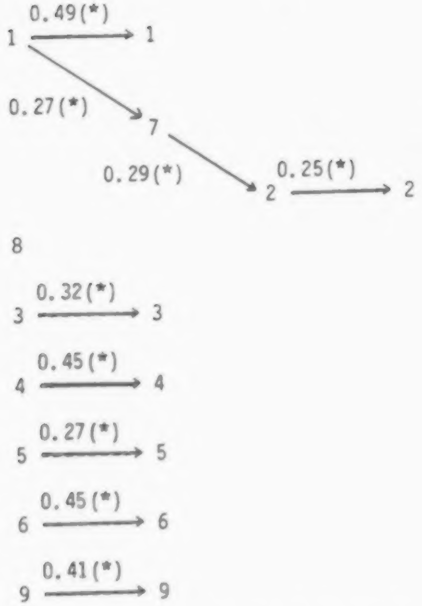


Figure 1: The Structure of Class 2 Dialogue.


0.49(*)
1
1
0.27(*)
7
0.29(*)
2
0.25(*)
2
8
0.32(*)
3
3
0.45(*)
4
4
0.27(*)
5
5
0.45(*)
6
6
0.41(*)
9
9

* Significant at the 0.01 level

Figure 2 The "Essential" Structure of the Themes in Class 2 Dialogue

Table 2 and Figures 1 and 2 summarize the content and structure of the dialogue. The total structure is dominated by the Themes 1, 7 and 2 - teacher-student discussion on mammals. Related ideas in Themes 8, 5 and to a lesser extent, 4 emerge and recede along with the dominant structure. The major theme of teacher-student question-answer interaction, Theme 1, provides a cohering umbrella under which the content is developed. The characteristics and types of mammals (Themes 7, 2, 8 and 5) and a comparison of them with reptiles (Theme 4) is the content being dealt with. Activities (Theme 3) using equipment (Theme 6) also occur. In Lessons 1 and 2, activities involving mice sometimes in their cages occur while in Lesson 3, the emphasis is on discussion rather than student activity.

A detailed analysis of the structure is given elsewhere (Clarke; 1987a), but, in summary, Class 2 is one where there is a lot of teacher-student discussion and where the discussion is focussed strongly on science content. The normal sequence of events is that an idea is introduced, mainly by the teacher, discussed for some time and then used to lead logically on to the next idea (e.g. cold blooded —> warm blooded) and/or a student activity. Specific aspects of the discussion are continually being related to a more general conceptual framework (characteristics of mammals) in the form of the classic Ausubelian subsumption model (Ausubel; 1963).

THE PROCEDURE USED TO COMPARE DIALOGUE STRUCTURES

If there are a number of dialogues, a comparison of their content and structures can be made by developing a number of content and structural criteria and rank ordering each of the dialogues on those criteria. The criteria developed for this study are:-

Structural:

1. The number of interpretable themes;
2. The percentage of variance explained by the themes;
3. The number of significant cross-correlations or the "coherence" among the themes compared to the total number of possible cross-correlations;
4. The number of cycles;

Content:

5. The number of themes the same as or similar to the themes identified in the corresponding text structure;
6. The number of themes explicitly related to content compared to the total number of themes.

A simple quantitative index of comparison can be obtained by finding the average overall ranking on all criteria.

A STUDY OF DIALOGUE IN SCIENCE CLASSROOMS

Conceptual Framework of the Study

The research reported here is based on a study of four Year 8 science classrooms studying the curriculum unit, "Mice and Men" (ASEP 108; 1973) in a large metropolitan secondary school in Brisbane (Clarke; 1987a). The study is conceptualized within a Lewinian B=f(P,E) framework and involves a multivariate analysis of selected "P" variables: student personality, motivational and cognitive characteristics, and "E" variables: curriculum materials, classroom dialogue and characteristics of the learning environment. The specific "P" variables used are Conceptual Level (personality), Locus of Control (motivation) and Piagetian Level and General and Specific Scholastic Aptitudes (cognition). The specific "E" variables are the "Mice and Men" curriculum unit, teacher-student and student-student audiotaped dialogue and student perceptions of the psychosocial characteristics of their science classrooms. The particular "B" variable focussed on here as the dependent variable is achievement.

Sample

The sample consists of three teachers and 113 students in four classes distributed as in Table 3.

Class	Teacher	N of Students		
		Male	Female	Total
1	A	13	12	25
2	B	15	14	29
3	C	14	14	28
4	C	16	15	31

Table 3 Distribution of Teachers and Students in Classes

The geographical location of the school is such that the student population is drawn from a cross section of socioeconomic backgrounds and the students are not significantly different from other Year 8 students in Queensland with regard to scores on compulsory standardized aptitude tests administered in October of Year 7.

Data Collection

Dialogue was collected on audiotape. All other independent variable information was collected by questionaire (Note 2). The dependent variable, achievement, was the student performance on the end-of-unit test prepared by the teachers of the unit. Three sequential science lessons, each lasting for 40 minutes, were audiotaped for each class during a normal school week. All lessons occurred in a science laboratory. Allocation of students to permanent laboratory seats, identification on tape at the beginning of each lesson and the normal use of names in interaction, ensured that all students could be identified. The tapes were transcribed and used in this study to provide input into the TSA Technique.

Analysis Procedures

(a) Comparison of the Dialogue Structures

Table 4 indicates that, on the basis of the criteria outlined above, Class 2 has, theoretically, the "best" structure followed by Classes 4, 1 and 3 in that order.

(b) Analysis of Data

Following the procedures recommended by Welch, Walberg and Fraser (1986), the analysis was done in two stages. First, a large number of independent variables were regressed on achievement. The independent variables used were age, sex, conceptual level, locus of control, Piagetian level, general scholastic aptitude, quality of the classroom dialogue and perceptions of the psychosocial characteristics of the learning environment. Appropriate conversion of non-interval variables to dummy variables was carried out (Nie, Hull, Jenkins, Steinbrenner and Bent; 1975). The structure of the dialogue (DIALSTR), locus of control (LOC), Piagetian Level (PIAGLEVEL) and general scholastic aptitude (SCHOLAPT) emerged as significant predictors of achievement. These were subjected to the second stage of the analysis and produced the results in Table 5.

The amount of variance of achievement explained by the variables is 21.9% (Note 3). The relative contributions of the variables to the explained variance are LOC: 13.97% [(2.321 : 16.611)x100], DIALSTR: 62.678%, PIAGLEVEL: 13.630% and SCHOLAPT: 3.678%.

	Class 1		Class 2		Class 3		Class 4	
Criteria	N	Rank	N	Rank	N	Rank	N	Rank
Structural:								
1. No of themes	8	2	9	1	6	4	7	3
2. Percentage of variance explained	38.7	4	73.8	2	71.8	3	79.6	1
3. Proportional coherence among and within themes	0.06	4	0.11	2	0.08	3	0.16	1
4. No of cycles	110	2	123	1	49	4	110	2
Content:								
5. No of themes the same or similar to the text	4	3	7	1	3	4	5	2
6. Ratio of content themes to total no of themes	0.38	4	0.89	1	0.5	3	0.86	2
Average of rankings		3.2		1.3		3.5		1.8
Overall Rank Order		3		1		4		2

Table 4 A Comparison of the Structures of "Mice and Men" Dialogues

Of the variables having an effect on science achievement in "Mice and Men" classrooms, by far the most influential is the structure of the teacher-pupil dialogue - the better the structure, the higher the achievement. Nearly two-thirds of the explained variance in achievement can be attributed to the dialogue structure. The students acceptance of personal responsibility for academic success and their level of abstract as opposed to concrete thinking also contribute but to a far less extent. The other variable, general scholastic aptitude, in this final analysis, does not contribute significantly.

Source	df	Sum of Squares	Mean Square	F Value	Prob
LOC	1	2.321	2.321	4.220	0.042
PIAGLEVEL	1	2.264	2.264	4.116	0.045
SCHOLAPT	1	0.611	0.611	1.111	0.294
DIALSTR	3	10.345	3.448	6.269	<0.001
Residual	108	59.375	0.550		
Total	114	75.986			

Table 5 Analysis of Variance of the Significant Variables influencing Achievement in "Mice and Men" Classrooms

CONCLUSION

This study indicates the responsibility that rests with the teacher in an activity-oriented classroom as far as providing the structural support necessary for effective learning (Note 4). The teacher is acting as a "surrogate textbook". Using their own organization of knowledge - albiet wrong or incomplete - teachers provide the structure that is lacking. As the results indicate, some teachers can do this better than others.

A challenge for teachers and teacher educators is to devise ways to improving the structure and sequencing of classroom dialogue. The TSA Technique could help here in two ways. It allows a sophisticated analysis of dialogue, indicating specific areas of weakness which could then be remedied by appropriate training. A similar approach has been used successfully with text material to rewrite and restructure deficient segments (Clarke; 1973). It could also be used to produce ideal "templates" of various models of teaching (e.g. Brady; 1985) for use as a guide for lesson planning.

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NOTES

Note 1. Only a brief indication of the procedure can be implied here. See Clarke and Carss (1988) for full methodological details. In the study reported later, the dialogue from four classes are compared. This dialogue comes from "Class 2".

Note 2. See Appendix 1 for details of the instruments used.

Note 3. $R^2 = 1 - (59.375 : 75.986) = 0.219$

Note 4. In a similar analysis of dialogues in a more traditional textbook-based setting using the same classes and teachers, the structure of the dialogue did not emerge as a significant predictor of achievement (Clarke; 1987a).

APPENDIX 1
Measuring Instruments Used

1. Conceptual Level

Interpersonal Topical Inventory
(Tuckman; 1964)

2. Locus of Control

Intellectual Achievement
Responsibility Questionnaire
(Crandall, Katkovsky and Crandall
(1965)

3. Piagetian Level

Bond Logical Operations Test
(Bond; 1976)

4. General Scholastic Aptitude

Test of Learning Ability (ACER; 1974)

5. Specific Cognitive Aptitudes

Reading Comprehension, Reading
Vocabulary, Mathematical Aptitude and
Study Skills (Byrne and Phillips;
(1981).

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"A MOST VALUABLE GROWING EXERCISE"

A report on the interaction of teachers with the action-research phase of LIPS (Energy)

Valda Kirkwood and Malcolm Carr

INTRODUCTION

The Learning in Science Project (Energy) (LISP(Energy)), a three year contract with the NZ Department of Education, carried out in the Science Education Research Unit (SERU) of the University of Waikato, began in 1985. The research was an investigation of teaching and learning about the energy concept in NZ schools (Kirkwood, Carr, Bell, McChesney, Osborne and Symington, 1986a&b; Carr et. al., 1986). After a "brainstorming" session and an initial phase of interviews with many science educators, a decision was taken to concentrate the research in junior secondary school classrooms (Forms 3 and 4, 13-15 year-olds) (Kirkwood, Carr and McChesney, 1986). Three case studies of current teaching practice about the energy concept (Kirkwood, Carr and Gibb, 1987; Kirkwood, Carr and Stonyer, 1987; Kirkwood, Carr and Shaw, 1987) resulted from intensive classroom observation using multifaceted data gathering. Phase 3 involved the development and trial of teaching materials and strategies to overcome or avoid some of the problems that emerged in the analysis (Carr, Kirkwood, Newman and Birdwhistell, 1987a&b; Carr and Kirkwood, 1988) of teaching and learning in the classrooms. This paper outlines the action-research phase, emphasising the teachers' perspectives.

ACTION-RESEARCH PHASE

The action-research phase of LISP(Energy) took two forms:

(a) trial of a preliminary package by the researcher with the usual teacher (Seddon) as an observer (role-modelling approach)

(b) trial of the subsequently-developed package by the three teachers (John, Judy and Sue) involved in the Phase 2 case studies (collaborative action-research approach).

In all cases the multi-faceted data gathering used in Phase 2 was used:

1. audiotaping of every lesson
2. observational accounts of every lesson
3. audiotaped interviews with students during the lesson
4. audiotaped interviews with the teacher before and/or after the lessons
5. audiotaped interviews with selected students out of classtime
6. keeping a teacher diary
7. pre and post surveys

In addition samples of selected students' work and all of the worksheets distributed to the class were collected. In the action-research phase this data gathering was supplemented by:

i the teacher in (a) above keeping a lesson-by-lesson diary which concentrated on the differences between how and what he normally taught and this set of lessons.

ii the students keeping a diary.

The collaborative action-research approach involved a continuing process of observation, analysis, implementation of improvements, observation, reflection and further analysis. John, Judy and Sue, during two days spent together with the researcher, reflected on their own and each other's case studies, the researchers' analysis of them, and the researcher's trial of the preliminary package. They made constructive suggestions for John to implement in his teaching of the package. At the end of John's trial they met together again for John to review his experience. Further reflection and analysis lead to an improved package for Sue to try. This same procedure was carried out at the end of Sue's involvement with the package and subsequently also with Judy's. This is illustrated diagrammatically in Table 1 at the end of the paper.

EFFECTS ON TEACHERS

Role Modelling Approach

Seddon sat at the back of his classroom, while one researcher taught his class, and a visitor to SERU (Dr. Barry Newman) acted as another researcher. Seddon was, for a considerable time, very sceptical about the whole venture. He refused to release his diary at the end of the trial. Instead he wrote very frankly about his feelings at the end of the trial. This report tells of his initial unease.

> When I was approached regarding teaching "Energy" to my third form I welcomed the idea because we had virtually decided not to teach it. Reasons we cited were: the

> difficulty pupils had in understanding the concept; the lack of practical activities; the poor response from our classes. I believed that the two researchers were doomed from the beginning and I was looking for evidence to support my prejudice. The first few lessons sought to explore pupil ideas on the use of the word energy, energy transfer and this was achieved by individual, group and class based tasks. There was little attempt by the teacher to tell the pupils the answers they should get. This continued exploration of pupil ideas highlighted pupil misconceptions and lack of knowledge in many areas of Science. This further reinforced my feeling that we were embarking on a pointless exercise.

However at the end of the month's research Seddon (who had been involved in previous LISP research) had changed his stance considerably.

> It was not until the sixth lesson that I could see the value of the approach being adopted and see that pupils were learning something about energy ... My real concern about the strategy is that it will be too easily dismissed by teachers because it does put to test their "control" of the class, it will require a great deal of preparation and time to assess where pupils are at, after each lesson. I see the main values of the approach as follows:
>
> 1. Pupils have their own views on what terms mean e.g. energy.
> 2. Pupils can put forward a large number of explanations for the same observations, all of which can be logical in terms of their own experience.
> 3. If we recognise and encourage pupils' explanations then they are more likely to listen to the hypotheses of other pupils and in the end those of the teacher.
> 4. Research of this nature helps identify those aspects of the topic which are (a) easy to attain, e.g. concept of energy change. (b) hard to attain, e.g. potential energy.
> 5. We have to get pupils to interact with concepts in more varied ways than we do at present, i.e. individual statements (looked at overnight by the teacher), group discussions (with nominated individuals reporting back), experimental work, etc.
> 6. We have to resist the temptation to give and define terms when so often we can create a need for a term "thing" - "something else" from an agreed generalisation or common pattern e.g. What do the following situations have in common? - compressed spring, stretched elastic band, battery, compressed air. Answer Ready to do something = potential.
> 7. If pupils cannot use a term easily either written or verbally then one needs to question whether it should be pursued at the particular level.
> 8. Pupils need to be encouraged to make accurate observations and explain them in their own words. They should be rewarded for presenting logical explanations even if they are not scientifically correct. Rewarding their efforts is only one step from their accepting that there are other points of view. It also challenges the teacher to present better evidence to support the scientific viewpoint. It is more important to get pupils to seek scientific explanations than to get them to accept without question the "right" answer.
> 9. Our methods of assessing pupil progress have to be re-examined. When I gave the standard recall test for this unit it did not tell (1) how well pupils could use the term energy or energy form in everyday speech or writing (2) their ability to modify their viewpoint in the light of new information.

Subsequently Seddon has used parts of the approach when teaching topics other than energy. He has spoken up at Science Teachers' meetings about the value of the research procedure in helping to understand the changes to teaching and learning recommended by LISP research.

Collaborative Action - Research

During the research John, Judy and Sue had opened their classrooms to the detailed observation described in working papers. Each teacher's classroom observation report, at the end of this phase, was given to the teacher for comment early in its preparation. John's comment about a sense of isolation reinforced the intention to bring the teachers together in collaborative action-research.

> You (referring to the researcher) go around and have a sort of team as it were. You're the hub of it so to speak. You understand we're sort of a, I find myself sitting out on a limb. I haven't been quite involved in knowing the other people that have been involved in this group. Perhaps if we'd been brought more together.

The supportive environment that developed in the collaborative group approach meant John, Judy and Sue's experiences differed considerably from Seddon's. Reading through their own and each other's case studies enabled them to reflect on their practice:

> The case study made us think about what we are doing, what we consider energy is and how we teach it (Sue).
>
> They were able to do their own analysis of the problems encountered.
> Most problems seen by each were similar (John).
> Different experiments and approaches uncovered and similar difficulties in all 3 studies (Judy).
> Basic similarity of approach and problems (Sue).

The degree of overlap between the four analyses (including that of the researcher) resulted in identification with the combined analysis. The teachers' suggested solutions to the encountered problems sat sufficiently comfortably with the researchers' for them to contemplate trialling the developed package.

This package involved the three teachers making changes to their classroom practice of teaching and learning about energy, in varying degrees, by:

1. incorporating a perspective of energy being
   - (a) an invention
   - (b) associated with change
2. finding out students' ideas and taking them into account in their teaching.
3. incorporating alternative teaching strategies e.g. posters of students' ideas, small group discussions, report-back sessions, whole class brainstorming.
4. allowing more open negotiation of systems discussed and investigated.
5. exploring students' ideas more rather than giving information.

John's comments at the end of the first day of meeting together indicate how helpful he found the interaction.

Account of session held at Valda's 27/5/87

I found the day rewarding and fruitful in several ways.

(1) We had the possibility to meet the other two teachers involved on the project. Having read their lessons I was naturally curious to meet and put a face to the authors of the other lessons.

(2) The day afforded me the possibility of thinking just about Energy free from the problems of school and home. This often showed up the limits of my thoughts about Energy and allowed others with their ideas to help enlighten me.

(3) Often time is needed to discuss ideas in order to clarify ones own ideas and the day produced many fruitful discussions on many issues not only energy.

(4) Finally, Valda's is a much more pleasant place to spend the day than at school. She is also an excellent hostess.

The empowering factor that this mutual support system gave the teachers throughout the action-research phase can be seen from comments written by the three teachers on the day when John reviewed his trial. John's trial was with a class which was not only deemed to be the least able but also the most disruptive and problematic fourth form in the school. John came to the meeting feeling very despondent about the whole experience. As he shared his experiences with the rest of the group a different perspective emerged. The following comments were written at the end of the morning session (a.m.) and then at the end of the afternoon (p.m.).

John's a.m. statement:
I feel more positive about the energy unit I taught. Good input from the other members of the group which have focussed down on to issues. I initially felt very negative about the unit of work with 4CS but the retrospective view has produced a more workable form.

John's p.m. statement:
Again a good session which focussed our ideas and pooled many others. Some positive suggestions for the future trials have evolved which should aid the other two. Good to talk over the teaching aspects in a non-threatening way.

Judy's a.m. statement:
I came with an open mind (empty mind?). Listening to John I realise he had a difficult task with this class, but optimistic results. I think after this a.m. that with variety in lessons, direction in thought and simplicity of experiments the approach to "energy" that is emerging is a great improvement on past. Group discussions definitely help to clarify ideas and approaches.

Judy's p.m. statement:
Positive feelings. Something concrete emerging almost suddenly (it seems). Practical ideas involving detailed worksheets an excellent idea.

> Sue's a.m. statement:
> Happier with group discussions (in class). See greater need for simplistic approach. More focus on different things? - yes - an actual process of activities. I feel encouraged and anticipatory - slightly daunted by thought of necessary preparation.

> Sue's p.m. statement:
> Feel even better as have a basis from which to work for my unit. Have consolidated some ideas about topic procedure e.g. group work and reported back. Formerly uneasy with this because of my lack of use of this method. Now prepared to give it a go. Realise the need to simplify. To some extent it seems we have reduced the 'content' to a few simple concepts to approach in different ways - rather like topics in English and Social Studies where students have the opportunity to explore an idea.

John's comment at the end of the research indicates the degree of thinking about the energy concept that resulted from the action research.

> I have been amazed at the complexity of this concept. The depth of thinking required to achieve some semblance of personal understanding has been valuable and necessary. I felt prior to this study that I had a reasonable understanding of energy but I have come to realise that not only my own but probably my teachers, including University Lecturers, were probably equally vague and tended to use terms which were ill defined. I feel now that I have a better understanding of the concept even if just to appreciate how complex and difficult a subject it is. I doubt that a complete understanding of energy is possible since it is a man made concept superimposed upon nature in a similar manner to "models" we create for our understanding of light and other natural phenomena. However I feel that this project has helped me to appreciate the concept more.

Indeed the very act of writing down their ideas initiated changes.

> In considering the idea of "energy" only in "change" I still have a few problems as I think some situations without change can usefully employ energy concept, e.g. fuels. Even as I write this, I can see how the "change" theme is applicable and necessary, although in the classroom last week in answering students questions about fuels, I found the "change" theme hard to use and desperately wanted to revert to the static (Sue).

Perhaps more importantly, this action-research on the energy concept provided an opportunity for reflection on each teacher's ideas of teaching and learning on much wider and deeper levels.

> The LISP teaching approach i.e. using students' ideas and incorporating them into the lesson structures has been valuable for me. I am now much more aware of the need to approach any modification of student ideas by being much more aware of where they are at when a topic begins. Some other valuable teaching approaches have also been made manifest e.g. the use of posters to display the students' ideas has been a valuable learning exercise for them. Students appear to be very interested in seeing

> their own and other work displayed. Methodology of research has been interesting and how results can be analysed and valid conclusions drawn has been, for me, most valuable (John).

> Involvement in the project has made me far more critical of documents and texts e.g. examiners' reports, S.C. exams and standard texts. I have become less of a "blanket marker" and consider students' ideas and justifications when marking work (even when against official school marks schemes). Because teaching is universal to people in N.Z., all have gone through the school system, surely research using students into its effectiveness and possible improvements should be a priority rather than the use of a few teachers' and experts' decisions as the operational structure for policy and curriculum (Sue).

This reflective process of action-research also initiated changes in their practices.

> I have attempted, and will further attempt, to use this approach (using students' ideas) in future topics next year (John).

> I have become keener to use a LISP approach in other subjects as a result of involvement in the project, and am amazed that the imminence of exams and my own legitimate absences have, to a large extent, precluded the approach I have wanted to take. I have been annoyed at relieving teachers twice giving students "the answers to write down" when I'd prepared worksheets for their ideas (Sue).

This account sketches some features of a complex interaction between four people who shared an experience in professional development as they confronted the difficult concept of energy with three very different classes. A summary of the benefits perceived during the collaborative action research follows:

(a) All the participants - teachers, students and the researcher began a process of change.
(b) All the participants developed an awareness of students' and their own ideas about energy.
(c) The teachers developed an awareness of their own and each other's teaching styles.
(d) The teachers became more aware of the fallibility of current assessment methods.
(e) The process enabled reflection, by all participants, on science and its concepts.
(f) The process provided a supportive environment.
(g) The process enabled the development of alternative teaching strategies.
(h) Tangible curriculum outcomes e.g. workshop materials were developed.

The positive aspects listed above have to be seen in the context where heavy demands were made on teachers' (and researchers') time and resources. Nevertheless the teachers and the researchers considered that they had achieved substantial professional development during this process.

Both the role modelling and action-research approaches used have considerable implications for pre-service and in-service teacher education, and will provide a basis for future discussion and papers.

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TABLE 1: Collaborative Action-Research Approach for LISP(Energy).

Reading and reflecting on own case studies (c.s.)

↓

Reading and reflecting on each others (c.s.)

↓

Group meeting - 3 teachers' analyses
- researchers' analysis
- 3 teachers' improvements
- researchers' improvements

↓

John's trial of 'improved' unit

↓

Group meeting - reflection of John's experience
- development of revised unit

↓

Sue's trial of revised unit

↓

Group meeting - reflection on Sue's experience
- further development of unit

↓

Judy's trial of further-developed unit

↓

Group meeting - reflection on Judy's experience
- curriculum package of suggested strategies

Research In Science Education, 1988, 18, 104-111.

PURPOSES ACHIEVED BY DRAWING DURING SCIENCE ACTIVITIES

Dorothy Hayes and David Symington

INTRODUCTION

This paper reports part of a larger study into the use by junior primary pupils of drawings in science lessons. There are a number of issues which come to mind when considering the significance of this activity. One of the issues which has been pursued in experiments reported by these authors is that of pupil satisfaction with their ability to produce appropriate drawings. It is believed that if the children are satisfied with their efforts this is likely to provide positive motivation for similar experiences. An earlier paper (Hayes and Symington, 1984) reported data which suggested that, in general, the pupils were satisfied with what they could achieve.

A second issue is whether, as some researchers believe, the children's ability to produce appropriate drawings is governed by their stages of development. Barrett and Light (1976), proposed that there are three distinct developmental stages in children's drawings. These three stages are labelled "Symbolic", "Intellectual realism", and "Visual realism". Other researchers (Symington et. al., 1981) have produced data which has challenged this developmental orientation. Some art educators have explained the data on which the stages models have been developed in alternative ways. Eisner (1972) states that, "the characteristics that children produce in their drawings and sculptures are products of both purpose and skill. When coping with a problem, the child, like the rest of us, brings to bear upon it those technologies of mind that seem to be relevant to its solution". The children apply problem solving techniques to the drawing activity. As similar solutions occur this has been interpreted as evidence of developmental stages. In the present study the drawings developed by the children are viewed as reflecting their knowledge of appropriate techniques, rather than as evidencing a developmental stage.

A further issue which needs to be addressed is whether children's drawings are able to achieve the purposes for which they are included in classroom activity. The choice of activities for classrooms is influenced by two conceptions of purpose. One is whether the activity will contribute to the "flow" of the lesson. For example, one reason for asking children to do a drawing may be to provide a quiet, individual task to help the children settle down after a boisterous, group activity. In this paper such purposes will be labelled as "process purposes".

The second notion of purpose which guides choice of activities is whether the activity is likely to lead to the achievement of the learning objectives the teacher has in mind. For example, whilst it may be decided to use drawing to settle the children down quietly, the nature of the drawing task should be related to the learning objectives the teacher has in mind. In this paper the purposes related to learning objectives will be described as "objective purposes". The study to be reported was designed to allow for exploration of both types of purposes.

METHODOLOGICAL CONCERNS

It was decided to gather the data in a context which was as near as possible to the normal classroom setting. Accordingly, the study was built around a series of lessons developed for junior primary grades. The topic "snails" was chosen because the animal is of obvious interest and appeal for children of this age, is suitable for first hand study and comes from the children's environment.

The lessons were based on the Interactive Teaching Approach (Biddulph & Osborne, 1984), with the children providing the questions they wanted answered, predicting outcomes, sharing information and ideas and suggesting how different aspects of the topic could be investigated. The teacher took on the role of fellow investigator, resource person, challenger of the children's ideas and facilitator of learning. As might be expected the children were involved in drawing activities regularly during the lessons. The drawings were used for a variety of process and objective purposes.

The Lessons

Lesson 1. The first lesson was designed to clarify the children's ideas about the topic and to provide the teacher with drawings and information regarding the children's knowledge and understanding of snails.

After a brief introductory discussion of pictures of insects found in the garden, the children were asked to draw a snail to show the teacher what it looked like. When the drawings were completed the children worked with a partner to discuss and list the characteristics, e.g., shell, eyes, that the partner's drawing of a snail showed them.

The children were then able to interact with their partner while observing an actual snail. They were encouraged to compare their initial drawing with the snail, then have a free activity/exploration time with their snail. The short class discussion that followed this exploration was used to list any questions that the children would like to have answered and any relevant observations they had made.

Next they were asked to draw their particular snail so that they could identify it in the next session. The resulting drawings were collected. With the completion of this drawing task the children again participated in a class discussion and additional questions or observations were listed. The children then grouped together the questions they felt should be investigated. Questions were grouped in the categories of food, movement and trail, body and shell. The children decided that an investigation of food would be the subject of the next lesson.

This paper will deal in particular with the data gathered in, and immediately after, the first lesson. Accordingly, the later lessons will be described in outline only.

Lesson 2. The second lesson started with the matching/identification activity, that is the children using the drawing produced in the previous lesson to find the particular snail they had observed. When the partners thought they had found their snail they were required to inform an observer of the reasons for the ease or difficulty of matching/identifying.

The children then investigated the question "What does a snail eat?" After their exploration they used a drawing to communicate something they had observed to their peers and teacher.

Lesson 3. The third lesson was an investigation of the children's questions about "Movement and Trails". They again communicated something they had observed during their investigation to their peers and teacher through a drawing.

Lesson 4. The fourth lesson was an in-depth investigation of the children's questions about the snail's body and shell, the children using a magnifying glass. No drawing activity was included in this lesson.

Lesson 5. Evaluation. This lesson took place two weeks after the session on "body and shell". This session was used to evaluate the unit of work.

Data Gathering

The data collected during this unit came from several sources:

- the children's drawings;
- notes made by observers during the lessons;
- individual interviews with the children after each lesson.

Drawings

The drawings were collected after each session and used as the basis for class discussions and individual interviews.

Observer Notes

The observers were the class teacher, a parent and two Victoria College second year student teachers. Each observed a group of children and recorded the dialogue and any other significant events during each session. An observer's guide sheet was supplied prior to each session with the activities listed and indicating what type of data should be recorded.

Interviews

Individual interviews with the children took place on the morning following the science lesson. After each session the children were interviewed regarding:

(a) their satisfaction with their drawings;
(b) factors that influence their ability to use drawings as a means of communication;
(c) whether their drawings achieved the purpose for which they were set.

ANALYSIS OF THE DATA

Only part of the data analysis can be reported here. This paper focuses on the question: "To what extent do the children's drawings of natural phenomena achieve the process purposes for which they were designed?" As explained earlier, process purposes are those concerned with the contribution of the activity to the "flow" of the lesson. Drawings were used for four such purposes in these lessons. These were:

(a) to focus the children's attention on the phenomenon;
(b) to help the pupils to formulate questions about the topic;
(c) to facilitate communication between children in the class;
(d) to keep the teacher informed of the children's thinking.

The data analyses reported here relate only to the first two of these. Further analyses will be reported at a later date.

A. To focus the children's attention on the phenomenon.

In the first lesson the children produced two drawings of a snail, the first from memory, the second as they observed the snail. The extra detail that the children put into their second drawing came from their observation of a real snail. The children's dialogue as they completed the drawing indicates how the task focussed the observation of many of the pupils. Some of the children's dialogue is shown in Table 1.

When interviewed, the children noted the differences between their first and second drawings discussing the increased detail in the latter. This information is shown in Table 2.

TABLE 1

Segments of dialogue as children completed their drawings.

Group 1

Catherine	- "Don't forget that bit of yellow, then we will be able to recognise it."
	- "Oh yes there's some black bits."
	- "Did you do that bit of plastic?"
Holly	- "That's not plastic."

Group 2

Annabelle	- "It's got spots on it's neck."
Miranda	- "It's got spots all over it."
Belinda	- "Yes, that's what I did - it's also got lines."
Annabelle	- "It's got a white bit in the middle. Maybe ours has different patterns."

TABLE 2

Detail noted by the children as present in the second but not the first drawing

Feature of drawing	Percentage increase in presence of the feature
Shell detail	82%
Antennae	78.5%
Body detail	57%
Size	43%
Colour	32%
Tail	21%
Eyes	21%
Trail	21%

Table 3 presents data which indicates the number of attempts the children needed to choose their snail from the class's collection. As can be seen in this table 81% of the children were able to match their snail in the first two attempts. The success with which the children could identify their snail suggests that they had been forced to carefully observe the snail to produce an adequate drawing.

TABLE 3

Percentage of groups who identified their snail, using their drawing on the first, second or third attempt.

Percentage of groups, who using their drawing, correctly chose their snail on the:

(n=21)	
first attempt (12)	57%
second attempt (5)	24%
third attempt (4)	19%

Observers recorded the dialogue between the children when they had successfully matched their snail. Some of this dialogue is shown in Table 4.

TABLE 4

Segments of dialogue after identification of snail

Group 1

Holly	- "It's got plastic like last time." - "It's the same size."
Catherine	- "There was a yellow squiggly line and there was black outside and the plastic was yellow."

Group 2

Miranda	- "It was easy to match because it had lots of patterns on it's shell."
Annabelle	- "Yes lots of lines on top of the shell and a bit of white on top."

After the matching activity when the children were interviewed again, the children who had easily identified their snail talked about using "shell detail" and "size" as factors that had been helpful.

B. To help the pupils to formulate questions about the topic.

This is an extremely important objective, as it is both the basis of this teaching approach and also an important way for young children to make sense of their world. The drawing activity appeared to stimulate the formation of questions as shown in Table 5.

TABLE 5
The number of questions, and the number of pupils asking questions, before and after the drawing activity.

	Before drawing activity	After drawing activity
Number of questions	15	22
Number of children who asked questions	15	24

As can be seen in Table 5 more questions were asked and more children were involved in formulating questions following the drawing activity. Throughout the unit of study the children continued to ask questions following each drawing activity.

The questions were classified in two ways to see if there was any significant difference between the questions asked before and those asked after the drawing activity.

The first method of classification was based on the content of the questions. No significant difference in the content of the questions asked before and those asked after the drawing activity emerged when the questions were grouped according to this criterion.

The second method of classification divided the questions into those that were investigable and those which were non-investigable. The basis for this classification came from an earlier study (Symington, 1977). The data from this second classification also showed no significant difference in the questions asked before and those asked after the drawing activity.

CONCLUSION

The data presented in this paper relate to the question of whether drawing activities met the process purposes for which they were designed. The choice of context in which the data were gathered and the methodology employed have shaped the form of answer which can be given to the question.

The data do support the assertion that involvement in drawing activities can encourage pupils to observe phenomena more closely and can stimulate questions. Further exploration of the issue using other topics, currently being carried out, will increase the confidence with which the findings of this study can be more generally applied.

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"READING" SCIENTIFIC DIAGRAMS: CHARACTERISING COMPONENTS OF SKILLED PERFORMANCE

Richard Lowe

INTRODUCTION

What happens when a student views an unfamiliar scientific diagram? In what respects does the way students look at scientific diagrams differ from the way their teachers look at them? How might increased understanding of such differences improve science instruction that makes use of diagrams? In this paper, some possible characteristics of diagram interpretation that distinguish individuals with different levels of expertise in handling these displays are explored. Because the factors involved in the interpretation of scientific diagrams have received comparatively little research attention, research referred to in the introductory section of this paper concerns visual displays and illustrations in general rather than scientific diagrams in particular. However, it is important to note that there are many characteristics of scientific diagrams that set them apart from other types of pictorial material. Because of these distinctive characteristics, specialised approaches, knowledge and skills may be needed to interpret certain types of scientific diagram effectively. Without appropriate specialised capacities, it is likely that for many students, the potential of diagrams as a tool for learning in science will be significantly diminished.

Pictorial Components of Instruction

Diagrammatic representation and a range of other pictorial techniques are increasingly used to supplement, complement and sometimes even replace textual presentation of instruction in science. However, little is known about the way students interact with these pictorial components of instruction. Although a number of authors have suggested schemes by which the supposed role of illustrations in instructional materials can be categoried and clarified (Levie & Lentz, 1982), empirical research that addresses the way such illustrations are mentally processed during learning has been largely neglected. Empirical studies of the role of pictorial material in instruction have tended to focus upon matters such as the difference in instructional efficacy of different types of illustration (Dwyer, 1967), the degree to which illustrations may facilitate comprehension or retention of material presented via text (Winn, 1982) and more recently, the way attention may be partitioned between text and pictures during learning tasks (Kirby, 1985). However, the cognitive processing of scientific diagrams themselves has remained comparatively neglected. Unless we better understand how individuals approach and work through their attempts to interpret scientific diagrams, any suggestions for improving instruction that involves such diagrams can at best address only some of the aspects that should be considered.

Investigating Diagram Processing

It is useful to begin a consideration of what may happen during the reading of diagrams by reflecting on some recent ideas about the reading of text. There has been a growing realisation that it is not just reading skills of a general nature that are involved in text processing (Marland, 1977). A number of skills that are quite specific to the particular type of text being read also appear to be involved. For example, it seems that expository material such as the text in science books requires a somewhat different form of processing from that required by narrative material such as literary works (Vacca, 1981). An outcome of this latter view of reading is the emergence of subject specific literacy as an important instructional issue. Accompanying the changes in conceptualisation of textual literacy, although far less widely publicised, has been the development of the notion of visual literacy (Sless, 1984). This notion can be extended to encompass the concept of subject-specific visual literacy which is based on the view that, contrary to conventional wisdom, pictorial materials are not all much the same but differ substantially according to their domain of application. If this degree of pictorial specificity is accepted as a legitimate constraint on the processing of instructional illustrations, then science teaching practices should take special account of the particular ways that scientific diagrams, as distinct from other forms of instructional illustrations, may be processed.

In considering possible components of the processing of scientific diagrams, it is useful to adopt a number of complementary perspectives. For the investigation of text processing, it has proven useful to employ a variety of levels of study ranging from broad considerations of the overall themes and macrostructures of texts to narrowly focussed explorations of the processing of individual semantic and syntactic components. Just as there are many general aspects common to the processing of a wide variety of forms of written text, so there are likely to be processing aspects that are common across a wide range of types of material based on visual images rather than words. Before considering the types of processing that may distinguish scientific diagrams from other forms of illustration, some more general aspects of visual image processing will be discussed.

Processing of Visual Images

An immediate problem with investigation of the way we mentally represent and process visual images is the covert nature of the cognitive structures and operations involved. Consequently, a degree of inventiveness is required in order to gain credible evidence for what may be taking place in a person's head while processing of visual images is proceeding (Shepard & Cooper, 1982). Researchers associated with the information processing movement have pioneered many approaches to the challenge of gathering data about the hidden and subtle processes that occur during cognition, particularly those that involve more sophisticated problem solving type activities (Newell & Simon, 1972). Another outcome of the work of these researchers is an appreciation of the importance of mental representation in activities that have a problem solving component such as those associated with many types of learning tasks (Kotovsky, Hayes & Simon, 1985).

The comprehension of an unfamiliar, instructional scientific diagram can be seen as a problem solving task in which the educational goal that is set for the viewer is to develop an interpretation of the diagram that is consistent with the intentions of the diagram's author (Lowe, in press). The degree of understanding (or misunderstanding) that is developed during this problem solving activity will be a function not only of the diagram itself, but also of the learner's own characteristics and goals as well as the context in which the diagram is encountered. Cooper (1980) has argued that all but the simplest visual images are processed by means of interactive processing in which both bottom-up (data driven) and top-down (concept driven) components are involved. Cooper has concluded that the perception of complex visual displays involves both global and local types of processing. She has further suggested that these qualitatively different forms of processing are continually interacting in a flexible manner as viewing proceeds in order to deal with the moment to moment demands of the task.

Cooper has also reviewed evidence that perception of visual displays can involve "chunking" processes by which viewers segment the whole of a display into a number of major subcomponents, each of which may in turn consist of some sort of grouping of lower level elements. The chunking processes referred to by Cooper appear to be governed by non specific semantic constraints such as those suggested by Gestalt theorists. However, there are numerous instances of the chunking of visual displays in which more domain specific semantic constraints are at work. These have been found in research dealing with a variety of subject domains (Chase, 1986). Typically in this research, individuals with high levels of expertise in the subject domain concerned were distinguished from non-experts not only because they knew more about the subject of the displays, but also because they had an approach to dealing with these displays that suggested a structured and usually hierarchically organised view of the material presented. This view was seen to be a reflection of a similarly arranged mental representation of the subject domain within the individual's cognitive structure. The information processing advantages of such a representation have been related to the way the associated chunking can allow the viewer to treat a complex display comprised of a large number of individual elements as a simpler pattern made up of a relatively small number of chunks. Further, the possession of an extensive and systematically arranged mental representation of the subject domain has been seen as facilitating cognitive operations within that domain.

Semantic and Syntactic Constraints

When an author devises a scientific diagram, choices must be made about a range of interrelated matters such as the amount and nature of information that is to be conveyed, what diagrammatic elements will be used to represent the chosen information and how these elements will be arranged. Decisions about these matters imply a consideration of the overall purpose and intended meaning of the diagram as well as the mechanics of the way it conveys its important messages to the imagined viewers.

With many of the scientific diagrams produced for instructional materials, constraints on the meanings associated with the diagram elements (semantic constraints) and constraints on the arrangement of those elements (syntactic constraints) are matters of loose convention rather than strict rule. In this regard, the symbol system to which such diagrams belong is in some ways less clearly defined and less well regulated than the system to which passages of written text belong. The use of labels and captions as textual adjuncts to the graphic components of scientific diagrams is a direct consequence of this difference in precision of the two symbol systems. However, for the many scientific diagrams where little or no textual elaboration is used, the lack of constraints on interpretation of the graphic components has the potential to cause comprehension problems. Even in cases where labels and captions are used, their extreme brevity can give them a cryptic quality that may be of little assistance to a novice in the area. If a multitude of interpretations is possible, especially considering the contextually improverished nature of most scientific diagrams, how is the viewer able to decide which interpretational path to follow? Clearly there will need to be a substantial contribution by the viewer if some scientific diagrams are to be interpreted satisfactorily. It appears that individuals who are skilled in the interpretation of particular types of scientific diagrams must rely greatly on what they already know about such diagrams to help them make sense of an example of one of those types they have not seen before.

The remainder of this paper will present selected results from an investigation of how a specific group of professional scientists differ from other individuals in the way they approach and work through diagram processing tasks. A major aim of this research is to identify differences in the way skilled and unskilled readers of scientific diagrams interact with these visual displays. Large differences in diagram reading skill between student and their teacher characterise the situation in which diagrams are being used as a resource in science lessons, particularly at an early stage of high school science study. Information about the nature of such differences has the potential to provide valuable guidance for the development of any programme of instruction directed toward the more effective acquisition of diagram interpretation skills.

Processing Meteorological Charts

At this stage of the research, science teachers and students have not been used as subjects because a preliminary goal had been to explore in a general way the question of what may underlie expertise in reading diagrams. In order to obtain sharply contrasted levels of expertise in diagram processing and to employ a type of diagram that was essentially free from textual elaboration, differences between professional meteorologists' and non meteorologists' approaches to weather map tasks were studied. Subsequent research will study the performance of students and teachers on tasks based on this same type of diagram.

The research discussed here examined the general approaches and specific strategies individuals adopted in attempting to complete a weather map for which they had access to only partial information. The tasks used were chosen to involve subjects in high level cognitive activity as a way of obtaining clues about the type of cognitive processing and structures that may characterise diagram interpretation tasks that are less artificial and more routine than the tasks used in this research. Subjects began with a blank outline map of Australia that had been divided into 30 equal approximately square-shaped regions. Their goal was to try to reconstruct a complete weather map for Australia that was hidden from their view. To help them do this, they were given the meteorological markings that were on just 10 of the 30 squares comprising the whole weather map. However, they selected which 10 squares they wished to have and chose them one at a time. A modified think-aloud technique, supplemented with probes about reasons for square choice and reactions to revealed information, was used to gather verbal data that might reflect processing strategies and aspects of mental representation. Details of the methodology and results have been reported elsewhere (Lowe, in press).

Figure 1 shows examples of the types of responses received from meteorologists and non meteorologists. Comparison of the approaches used by these two groups suggests that the meteorologists tended to concentrate their efforts in some parts of the diagram whilst virtually ignoring others. There was a great deal of unanimity amongst the meteorologists about the identity of these "important" and "unimportant" regions. In contrast, the non meteorologists chose in a more varied and less discriminating fashion, tending to select squares that were much closer to each other on average than the squares chosen by the meteorologists. Further analysis showed that the meteorologists tended to choose groups of squares that allowed them to explore regional "chunks" of meteorological information. An important instance of this chunking approach was evident in their early efforts to determine the season of the year represented by the weather map. This determination was usually accomplished within the first one or two squares by attempting to locate the position and shape of a distinctive seasonal feature such as the subtropical ridge or the west coast trough. Once the general season had been established, it appeared that this knowledge played a major role in guiding decisions about the subsequent regions in which squares were to be selected. Thus, two distinct but interacting forms of chunking were apparent. One was a spatial chunking associated with the division of the map into meteorologically more and less informative regions. The other was a temporal chunking of the year into various seasons and parts of seasons.

For the meteorologists, the features on the map appeared to be related to each other in a hierarchial manner both in terms of nested patterns and subpatterns of markings and in terms of their relative probability in a given location during the season in question. In contrast, the non meteorologists' explorations suggested that they had few specific constraints, such as hierarchical relationships, to guide their selection of squares. The non meteorologists seemed to have little idea of where they should look to find key information and even when they did stumble across it, they did not appreciate its signficance. The performance of the meteorologists was characterised by a concern with groups of lines and not merely with individual line segments. This was evident both in the square selection phase of the task and in their later attempts to complete the whole map by adding their own markings to the partially revealed map. However, the non meteorologists were rarely concerned with markings at any level of hierarchy above that of individual line segments. They tended to remain "stuck" at this single level while the meteorologists alternated frequently between global and local approaches to the meteorological markings. In fact, merely describing the meteorologists' processing as either global or local does not capture the great range of levels of analysis that they employed. In some instances meteorologists took account of the subtle curving of a tiny line fragment in a corner of a single square. In other cases these subjects considered the typical spacing of lines within a region made up of a group of squares. In still other cases, they considered the general pattern that was building up over the entire map.

Once subjects had received their full quota of 10 squares each, they tried to complete the map by drawing in any remaining markings they thought were present on the hidden map. The non-meteorologists' performance of this completion phase of the task was characterised by (a) the addition of fewer lines to the map than were added by the meteorologists and (b) a tendency for those they did draw to be interpolations across only one or two blank squares. However, the meteorologists tended not only to interpolate across a greater number of blank squares, but also to produce more extrapolations beyond their known information. Further, much of this behaviour could not be satisfactorily explained in terms of the simple continuation of a line according to a previously established tendency. Rather, quite fundamental changes in line direction and curvature were often involved. In some extreme instances, whole lines or other markings were added that were in no way connected physically with other lines. Despite their lack of any obvious physical relationship to lines that a subject had previously established actually did exist on the hidden map, a high proportion of these additions were essentially correct. This capacity to make substantial and largely appropriate inferences about markings over comparatively large areas of the map supports the view that meteorologists have a rich, hierarchically organised and well interconnected mental representation of weather maps. It is of course not surprising that meteorologists know a great deal more about weather maps than non meteorologists. However what is of interest is the apparent interrelationship of this knowledge that gives them such an impressive capacity to go beyond the available information. This type of enhancement of information processing would seem to be particularly beneficial in the interpretation of abstract diagrammatic material because of the capacity it gives the viewer to supplement the terse depiction in the diagram with a substantial and appropriate contribution of their own.

"Natural" Diagram Interpretation

There is reason to believe that despite the artificiality of the diagram processing task described above, some aspects of what was observed may point towards what is involved when a diagram is interpreted under more natural conditions. For example, it has been suggested from studies of the eye-movements made by people reading maps that skilled viewers concentrate their attention on more informative regions in the maps (Antes, Chang, Lenzen & Mullis, 1984). Further, the particular goal set held by viewers appears to be related to the pattern of eye movements they make when inspecting a pictorial display (Yarbus, 1967). Although eye-movements studies at best offer only very indirect indications of what may be happening at a cognitive level, the findings produced by this methodology are generally consistent with the results obtained by the more intrusive methodology used in the weather map research referred to above.

If the responses to the weather map task do in fact reflect a number of aspects of natural diagram processing, then some speculations are possible concerning the characteristics of those who are unskilled in the reading of scientific diagrams. It seems likely that a viewer who is unskilled in interpreting a particular type of scientific diagram will have a poor mental representation of that type of diagram. A representation could be classed as poor because of deficiencies in the amount of information it contains, the nature of that information or the way that information is structured. One possible consequence of a poor mental representation is that the diagram being viewed may overwhelm the viewer, especially if it is a rich or complex display such as an elaborate circuit diagram. (This aspect of the richness of a scientific diagram will be explored in more detail in the following section.)

Another possible consequence of a poor quality representation is that a viewer may have little sense of what information within the diagram is particularly salient to its interpretation. Even if some of the more important regions were singled out, it is unlikely that the full significance of these regions would be appreciated. It is one thing to have your attention attracted to an important area of a diagram and quite another to interpret correctly how information in that area is related to (a) information in the rest of the diagram, (b) the referents that the diagram depicts or (c) other aspects of the subject of the diagram that are highly relevant but which are not depicted by the diagram (Lowe, 1987).

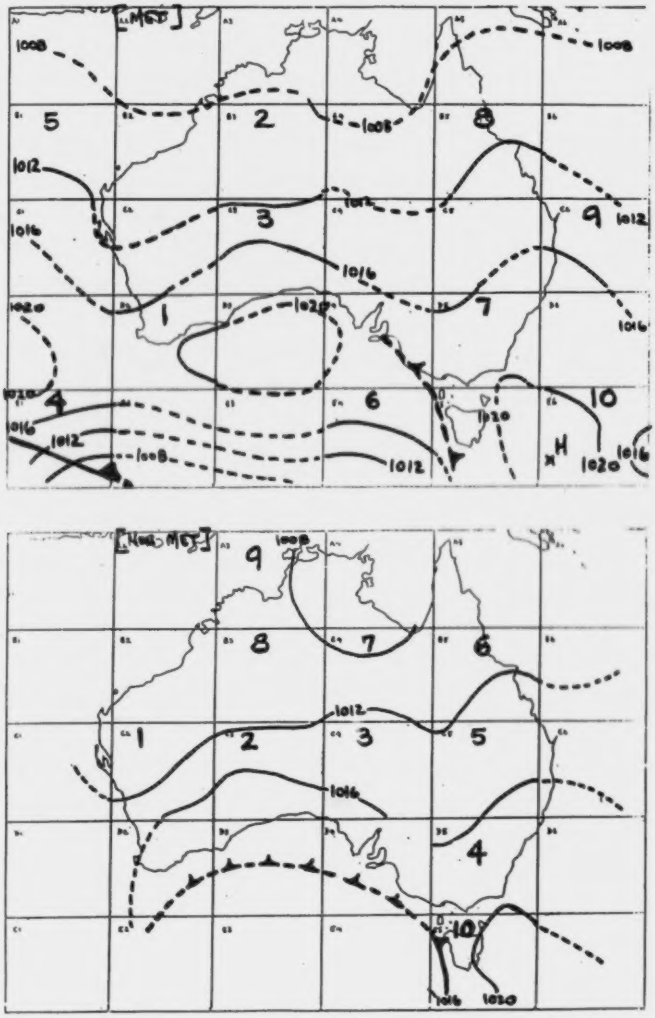
Context and Richness in Scientific Diagrams

The notion of "richness" raised above deserves further consideration because of its potential to affect processing of diagrams in a number of rather different ways. One way in which a visual display may be rich is in the sense that it contains a great deal of supplementary, explicit contextual information that helps the viewer establish an appropriate framework for interpretation. However, this is often not the case for scientific diagrams because of their concern with extreme economy of representation. For scientific diagrams, a rich display (one with large numbers of elements and relationships depicted) is not usually rich because it contains a generous supply of supporting, acilliary material to help in the establishment of an interpretational framework. Rather, it just needs to depict a large mass of information, all of which is essential to the strict scientific purposes of the diagram. Such a wealth of information may overwhelm the information processing capacity of the unskilled viewer. A rich external representation can be made more cognitively digestible if a person's internal representation contains organising rules and patterns that allow the display to be handled as a small number of related chunks rather than as a myriad of individual unrelated elements. This form of mental representation appears to characterise those who are skilled in the reading of weather map diagrams.

Many scientific diagrams are not especially visually rich and appear quite simple. Such diagrams contain a relatively small number of uncomplicated diagram elements that are arranged in a clear and straightforward manner. All context and "unnecessary" information has been stripped away so that what remains is the essence of the subject matter being depicted. The comprehension of such minimal diagrams may require the viewer to make a substantial contribution to the information on the page. In many cases this contribution will largely serve the functions of context setting and elaboration. Both of these contributions are necessary in order to set the constraints that define the interpretational framework and subsequent processing of the diagram. The lack of richness in the display must be compensated for by a very rich and appropriate mental representation on the part of the viewer. If this is not present, the viewer may cast about amongst his or her cognitive structure to find any material that could form some sort of a framework within which interpretation can proceed. Failure to find such a framework may mean that the viewer will be quite bewildered by the diagram. The presence of an inappropriate interpretational framework or the complete absence of any form of framework are likely to severely prejudice the instructional utility of the diagram in question.

CONCLUSION

The interpretation of scientific diagrams has been characterised as a complex process. This contrasts sharply with an apparently widespread view among producers and users of resources for science teaching that they are generally unproblematic and that their meaning is usually quite transparent. The continued currency of this view is a matter of concern, especially when resources for learning in science are now so heavily based on pictorial presentation. It is likely that students who are new to scientific diagrams as a pictorial genre will look at them in a manner that is quite different from the way they are seen by their teachers. What seems to a teacher to be a straightforward and clearly presented depiction of a scientific concept, process or structure may be a mysterious and impenetrable abstraction to a student. Whereas the teacher is able to identify readily the elements of a diagram and link them into a coherent, meaningful whole, the student may misunderstand what it is that is depicted and how the depicted entities are related. A critical factor underlying such differences appears to be the extent and nature of the mental representation of student and teacher. Both of these aspects of the mental representation of scientific diagrams would probably have to be addressed if there are to be improvements in the development of students' diagram interpretation skills. It does not seem sufficient merely to give students a huge diet of diagrams and assume that the necessary reading skills are either present or will develop by themselves. Rather, a deliberate programme designed to develop well structured mental representations of scientific diagrams should accompany efforts to build up an extensive knowledge base about this highly specialised form of visual display. Such a programme should be accompanied by instruction that develops appropriate processing strategies that allow students to gain maximum value from the diagrams they encounter.


[MET]
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1016
1020

FIGURE 1

Examples of (a) meteorologist and (b) non meteorologist weather map search and completion. (Search sequence is indicated by large numerals, revealed information by solid lines and subject's additions to complete map by dotted lines).

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COGNITIVE LEARNING STRATEGIES AND OUTCOMES IN A HEAT TRANSFER EXPERIMENT

Gloria Dall'Alba

INTRODUCTION

In this paper the nature of individual differences in performance is explored for several learners in an experiment about heat transfer. This study differs from other studies of heat transfer (for example, see Erickson & Tiberghien, 1985) in that its principal focus is the relation between learning strategies and outcomes in the heat transfer experiment rather than the students' understanding of heat transfer.

THE EXPERIMENT

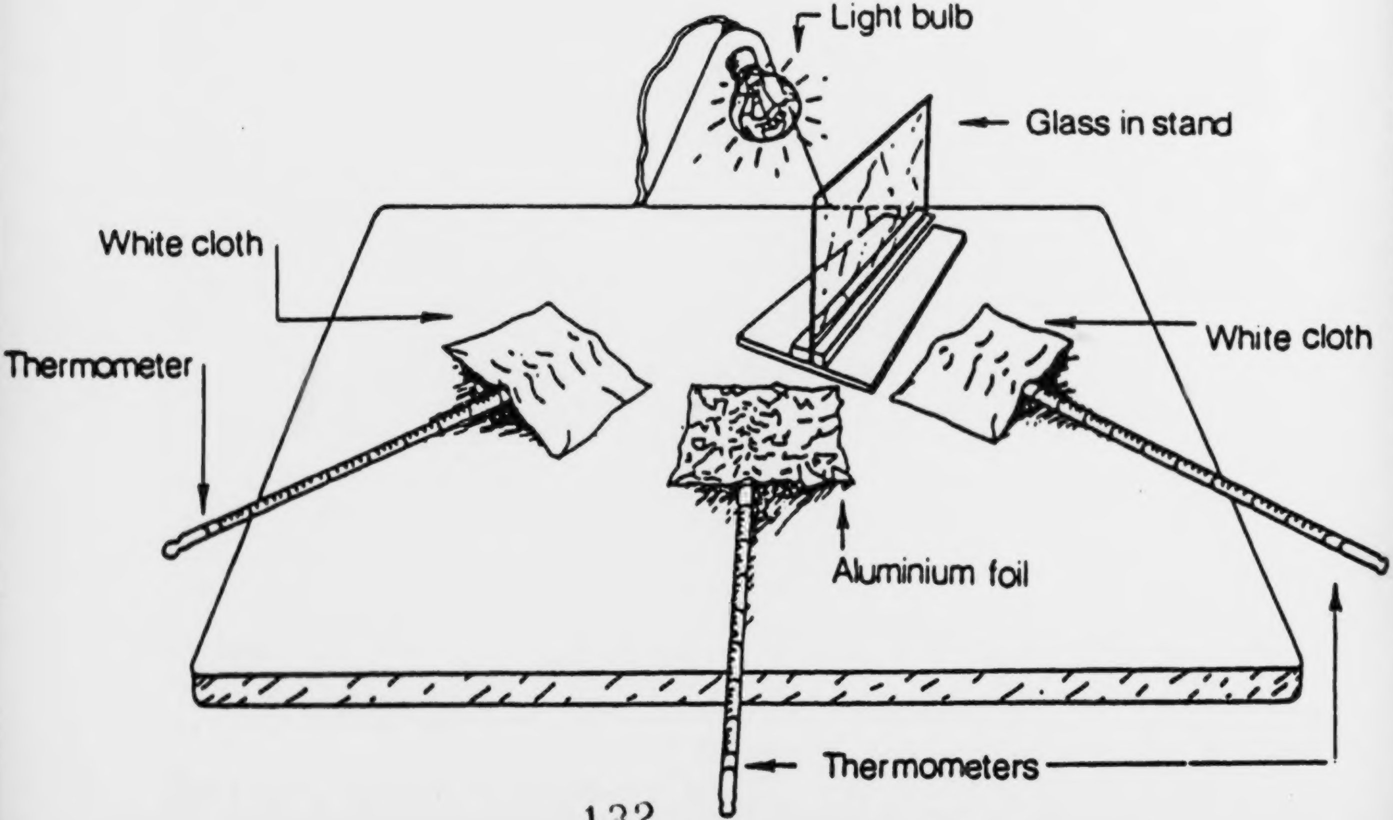
Ten secondary students aged from 13 to 15 years engaged in the heat transfer experiment. The experiment was adapted from an Australian Science Teacher Education project task (Northfield, 1976; Task number CC/5.3). The learners were provided with the necessary instructions and apparatus. They were required to place three thermometers under a light globe, each covered with a different material, and to record the temperatures at fixed time intervals (See Figure 1). During the experiment the learners were encouraged to "think aloud". Each interview was audio-taped and, subsequently, transcribed.

After recording the temperatures, the learners wrote answers to questions that required interpretation and application of the results, for example:

Which thermometer showed the most rapid rise in temperature?

Which material would be most useful in keeping a house cool in summer? Why?

EXPERIMENT ON HEAT TRANSFER


Light bulb
Glass in stand
White cloth
White cloth
Thermometer
Aluminium foil
Thermometers

Later, they responded to more general questions:

What did you think you were being asked to do?
What was the experiment about?
What did you do in the experiment?
What did the experiment show?

The learners' responses to these questions, in conjunction with their performance in the experiment, provided data on their interpretation of the problem, method of solution, and learning outcomes.

OBTAINING EVIDENCE OF STRATEGY APPLICATION

In studies of learning, the data consist of those features of learning performance that become evident to the researcher. Some aspects of the learner's experience are not communicated. Hence, the data on learning performance may be incomplete and limited. In this study the use of several sources of data considerably enhanced the completeness and accuracy of the data.

The first and most direct source was the think aloud data. The instructions that were used to introduce the experiment included the statement, "As soon as you begin I'd like you to tell me what you're thinking about". Since a detailed account of the learners' engagement in the task was required, it was important that concurrent reports (that is, during the event) were obtained.

The second source of data was concurrent, written observations by the interviewer. These observations permitted triangulation (that is, checking the validity of data using another source) and so, provided supporting evidence for the application of particular strategies. They enabled the plausibility of the learners' verbal reports to be checked. In addition, they provided data which supplemented the other sources.

Directed, specific probes were a third source of data. They were used to ensure that the interviewer's observations or interpretations were consistent with the learners' experience and perceptions. For example, during the experiment the interviewer questioned a learner, Paul, after observing that he consistently read the temperatures from the three thermometers in the same order:

I. Each time you seem to be reading them in the same order. Are you aware that you were doing that?
P. Yeah.
I. Are you doing that for any reason?
P. Well, this one's easier to read.
I. So you read that first?
P. Yeah, 'cos it's facing this way and also it's that side.

I. Ohh. O.K.

P. And it's just closer and dunno.

The use of such probes reduced the likelihood of incorrect interpretations. Similarly, the use of specific probes enable the clarification of some of the statements that the learners made while thinking aloud.

A fourth and retrospective data source was a checklist of statements indicative of learning strategies, for example, "I thought about other things I know about heating or thermometers" and "If I didn't understand I did something about it". The checklist was based on Baird's (1984) Tentative Classification Scheme For Some Evaluation Strategies Involved in Learning Written Information. Immediately after completing the experiment, the learners selected those checklist statements that were applicable to their performance. They then discussed with the author/interviewer each statement that they had selected. The discussion of the checklist statements served to clarify some of the think aloud data. In so doing, it provided supporting evidence for the application of particular strategies.

In addition to clarifying the think aloud data, evidence of additional strategies emerged from the use of the checklist. When the learners were engaged in the experiment, it was likely that their verbal reports would be incomplete. The checklist provided supplementary data which was necessary to the construction of an account that was as complete as possible. Each statement was specific and referred to an event that did or did not occur. The discussion of the checklist statements was directed to establishing when the events occurred, with the learners giving specific examples.

IDENTIFYING THE APPLICATION OF LEARNING STRATEGIES

The strategies that were the focus of the study involved metacognition, that is, they involved knowledge, monitoring, and control of the learners' own cognition. (This concept of metacognition follows Flavell's (1976) definition). The strategies were defined as the questions or decisions of the learner relating to discrete steps or actions taken in performing a task. For example, in carrying out an experiment a learner might (a) decide how to implement the instructions, and (b) while implementing them, judge whether the procedure is likely to be successful.

The strategies that were applied by the ten learners in the experiment were identified. Strategies which fell into the following groups became evident from the learners' performance: (a) interpret what the experiment is about, (b) interpret and implement the instructions, (c) monitor and control the implementation of the instruction, (d) monitor and control the progress of the experiment, (e) interpret the results in relation to and beyond the experiment, and (f) evaluate the method or results. Table 1 contains examples of the strategies that occurred in each group.

QUALITY OF STRATEGY APPLICATION

In addition to variation in the strategies that were applied by individual learners, there was variation in the way in which strategies were applied. For example, both Jan and Laura made an error in assembling the apparatus. Jan attempted to correct the position of the apparatus but failed to accord with the instructions. In contrast, Laura corrected her error in positioning the apparatus so that it accorded with the instructions. The application of strategies was found to vary in quality.

In the context of this study, quality refers to the extent to which the application of the strategy was relevant to the task, contributed to the successful completion of the task, and incorporated control over the learning. The application of a strategy is not the most significant factor, per se, but rather, the quality of application of that strategy.

The first and second aspects of the quality of strategy application, namely, relevance and contribution to the task, are self-explanatory. The third aspect was identified with reference to Flavell's (1976) distinction between monitoring and control of learning. It was concerned with the extent to which monitoring of learning was associated with control. Several learners monitored both the way in which they engaged in the experiment and their level of understanding. These learners varied in the extent to which they utilised the resultant awareness to exercise control over their learning. For example, Paul compared the temperature readings with those he expected. He was surprised at some of the differences but accepted the results he had obtained. Stan, too, was surprised at some of his results. In contrast to Paul, he actively sought to establish why the results differed from his expectations. Stan used the monitoring of his learning as the basis for exercising control over it.

STRATEGIES AND SUCCESS ON THE EXPERIMENT

The learners' success in completing the experiment was assessed in relation to what the experiment required. The interviewer closely analysed the experiment in order to make explicit its nature and requirements. The interview transcripts were used in the analysis. This means that the analysis was based on a rational examination of the requirements of the experiments and on performance.

The heat transfer experiment required that the learner (a) determine the purpose of the experiment, (b) assemble the apparatus according to the instructions, (c) carry out the experiment as instructed, while maintaining the position of the apparatus, (d) record the results, and (e) interpret those results. The learners' performance in meeting these requirements is summarised in Table 2.

In general, the learners were able to answer specific questions that involved interpreting the meaning of the results and applying them to other contexts. However, they were less successful in explaining and justifying their interpretations (Refer to Table 2). The question with which many learners had greatest difficulty was explaining why the temperature did or did not stop rising. In addition, several learners were unable to justify their application of the results to a given external context, namely, keeping a house cool in summer. (It should be noted that the answers to the questions were assessed in relation to each learner's temperature readings, not to an "objective" answer. Hence, two opposing answers both could be considered correct, provided that they accorded with the results to which they referred. Furthermore, the accuracy of the learners' experimental procedure was not taken into account when evaluating their interpretation of the results).

The variation in strategy application and the interaction between the strategies and the steps taken in the experiment is illustrated by the performance of Jan and Owen. (Instances of strategy application are highlighted by underlining.) As Table 2 shows, in contrast to Owen, Jan failed to meet many of the requirements of the experiment. Her performance would have been improved with the effective use of appropriate strategies for monitoring and controlling her implementation of the instructions.

Jan applied several strategies concerned with interpreting and implementing the instructions. She began the experiment by setting up the apparatus step-by-step without first reading all the instructions. She used the diagram to assist in assembling the apparatus but failed to accord with the instructions. Initially, she placed the thermometers as instructed but moved them all out of position when inserting the glass, failing to control the distance from the globe. Jan sought to determine one of the requirements of the experiment without referring to the instructions when she asked, "Am I supposed to record those temperatures?". In that instance, she displayed a lack of independence in and reluctance to exercise control over her own learning. She related the experiment to a science topic which she was studying at school. In so doing, she related prior knowledge in a way which contributed to task completion or understanding.

Jan's application of strategies for monitoring and controlling her implementation of the instructions was of low quality, making little contribution to task completion. During the experiment she attempted to correct the position of the apparatus but failed to accord with the instructions. She reported that, at the end of the experiment, she considered whether the experiment had been completed without taking steps to find out. She made an attempt to interpret the results when she compared the temperature readings with her prior expectations, although she was unable to justify those expectations.

TABLE 1

Examples Within Strategy Groups From the Experiment

Group 1	Interpret what the experiment is about
	Question the purpose of the experiment without attempting to determine it.
	Determine the purpose of the experiment
Group 2	Interpret and implement instructions
	Clarify the instructions by re-reading, prior to assembling the apparatus
	Position the thermometers in relation to prior knowledge of "movement" of heat, deviating from the instructions
	Seek to clarify the diagram when assembling the apparatus without referring to the instructions
Group 3	Monitor and control implementation of the instructions
	Take care to maintain the positions of the apparatus during the experiment
	Attempt to correct an error in positioning the apparatus but fail to accord with the instructions completely
	Assess whether the experiment is being completed correctly, according to the instructions
Group 4	Monitor and control progress of the experiment
	Check temperature reading which differs from that expected
	Predict next temperature reading from pattern of previous readings
	Monitor temperature reading in relation to other temperature readings
Group 5	Interpret results in relation to and beyond the experiment
	Consider the probability of the temperatures decreasing
	Use prior knowledge to explain reasons for relative temperature readings
	Predict relative temperature readings but have no justification for the predictions
Group 6	Evaluate method or results
	Assess method of carrying out the experiment with reference to results obtained/task requirements
	Question the reason for using this method for the experiment but accept it as given
	Compare the relative temperature increases to determine whether the results are acceptable.

When Jan was questioned about what the experiment was about she replied, "Just the temperature and how much that was rising up". She saw the experiment in terms of one aspect and, hence, failed to grasp its purpose, namely, comparing the heat transfer of different materials.

TABLE 2. Learner Performance in Meeting Requirements of the Experiment

Requirements of Task	Learner									
	Jan	Laura	Paul	Norm	Helen	Ron	Owen	Meg	Stan	Kay
Interpret purpose as intended	-	x	x	x	x	x	x	x	x	x
Set up as instructed	-	-#	x	x	#	-	#	x	-	#
Maintain apparatus in place	-	-x	x	-	-	-	x	-	x	x
Record: T0	-?	x	x	x	x	x	Only 1	x	x	x
T1 to T6	x	x	x	x	x	x	x + T7	T1-T5	x	x
Interpret temperatures*:										
1. Compare across columns and select highest	x	x	x	x	x	x	x	x	x	x
2. Compare across columns to find most rapid rise	x	-	x	x	x	-	x	x	x	x
3a. Within columns find if temperature stopped rising	x	x	x	x	x	-	x	x	x	x
b. Give reason for a. above	-	-	-	-	-	-	x	-	-	x
4a. Interpret temperature as heat absorbed and compare across columns	x	x	x	x	x	x	x	x	x	x
b. Apply to broader, external context	x	x	x	-	x	x	x	-	x	x
5a. Apply results to given, external context	x	x	x	x	x	x	x	x	x	-
b. Justify application in a.	-	x	x	x	x	x	x	-	x	-

Key to Symbols

x Requirement was met	# Distance from the glass was controlled, not from the thermometers
- Requirement was not met	* Refer to Figure 1 for the whole question
T0 Initial temperature	

Jan was able to answer questions about the temperatures obtained and the application of the results to other contexts. However, she was unable to answer the questions that extended those ideas and required explanation and justification (See Table 2). When she was asked, "What did the experiment show?", Jan once again responded in terms of the temperatures:

J. I was sort of surprised with my results.
I. How do you mean?
J. That one (cloth and glass) was so low and the other one (cloth only) was 7° higher... I would have expected that they'd all have been about 3° the difference and that they wouldn't have been that much.

Jan's strategy application displayed the same failure to focus on the purpose of the experiment. She attempted to carry out the instructions but failed to see the individual steps in relation to one another and as a whole. She neglected to monitor effectively her implementation of the whole set of instructions and the progress of the experiment. This resulted in errors in following the instructions (see Table 2), as the experiment demanded more than following a recipe for an experimental procedure. It required interpreting the underlying purpose in relation to the individual steps.

Owen was more successful than Jan in meeting the requirements of the task, as Table 2 shows. He was also more active with respect to strategy application, applying strategies from each group. Before beginning, he made an initial attempt to interpret what the experiment was about. After seeing the apparatus but before reading the instructions, he decided that the experiment was about light or heat.

Owen applied strategies concerned with interpreting and implementing the instructions. He read the instructions and questions to answer then set up the apparatus without referring to the instructions or the diagram. This suggested that he had an overview of how the apparatus should be assembled. He claimed that, throughout the experiment, he thought about related experiments that he had done at school. He related prior knowledge in a way which contributed to task completion or understanding.

Owen's strategy application included monitoring and controlling the implementation of the instructions. For example, he corrected an error in how he was using the thermometer, so that his results would be accurate. He also monitored and controlled the progress of the experiment. When taking temperature readings, he monitored how carefully they were being read and recorded. He checked a temperature reading which differed from what he expected.

He applied several strategies for interpreting the results in relation to and beyond the experiment. As he recorded them, he monitored his understanding of the temperature readings and compared the temperature with his prior expectations. He used prior knowledge to explain the reasons for the relative temperature readings. During the experiment he considered how the temperature readings could be used to answer the outcome questions. He also related the use of the results to school and everyday contexts. Owen evaluated his method of carrying out the experiment when he obtained unexpected results. He questioned the correctness of the method, based on the monitoring of those results.

As Table 2 shows, Owen successfully answered all of the outcome questions, unlike the other learners. He was able to answer the specific questions that required interpreting the results and applying them to other contexts. In addition, he explained and justified his interpretation of the results.

When he was asked, "What was the experiment about?" and "What did the experiment show?", he expressed the purpose and the results in terms of the heat absorption of different materials. His strategy application displayed the same view of the experiment as a whole, not as a series of separate steps. It showed that he sought to comprehend the experiment and the results. His strategy application was relevant to the task, contributed to task completion, and showed that he exercised control over his learning. Hence, it was of consistently high quality. In conjunction with the high quality of strategy application, his outcomes were of high quality.

CONCLUSION

The relation between the strategy application and the learning outcomes from the experiment displayed a similar pattern to that of other tasks performed by the same group of learners (Dall'Alba, 1987). The quality of strategy application was found to be a significant factor in determining the degree of success in the experiment. The most successful learners were consistent in maintaining a high quality of strategy application. In contrast, the less successful learners failed to apply the necessary strategies or their strategy application was of low quality.

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PROBLEM SOLVING AND THE VIDEO PRACTICAL:

THE IRON WOOL/ACETIC ACID EXPERIMENT

P.P. Lynch and T. Shadbolt

INTRODUCTION

Practical work and some implicit general background issues

This paper describes one of a series of studies intended to extend the contribution of practical work to science teaching. Though most science teachers and educators would advocate the use of an extensive practical component, the structures and strategies required to do this are complex and not usually well-developed (Lynch 1987). The lack of supportive structures and strategies, particularly in relation to assessment, no doubt explains why many well-intentioned programmes aimed at promoting experimental work have largely failed - from Henry Armstrong's heurism to more controlled curricula such as Chemstudy.

It goes beyond the bounds of the paper to fully review the complexity of possible strategies but it would seem essential that what is contained herein should be seen as contributing to an understanding of the general picture. Perhaps the following four guidelines serve to capture the main general background issues for this study and for the series of studies as a whole:

(1) To develop some sort of skill mapping which is usable (for assessment) and which can be shown to be reliable and valid.

(2) To relate the mapping of the practical component to that for "theory", using the same language and constructs.

(3) To develop instruments and procedures to deal with the practical mode for both continuous assessment and formal examinations.

(4) To develop and communicate a common language and conceptual structures to deal with the issues involved - essentially a meta language for the purpose of dialogue.

The main thrust of this paper is associated with guideline (3) and in particular to explore the formal examination of practical work. However, although the study is initially an exercise in action research, the data gathered and its interpretation afford a retrospective study of usability, reliability and validity. In the end, all four general guidelines/background issues are addressed.

Practical Work and Problem Solving

Practical work would appear to be an activity which in principle lends itself to the development of problem solving skills. Nevertheless, at the beginning of this study we were surprised at how many science teachers perceived practical work to be mainly about manipulative skills, observation and recording. This no doubt relates to ambiguities about the meaning of the term "problem solving" itself. It is a term much used by educators, psychologists and scientists, who use it with slightly different meanings as they tend to argue its case from different roots: educational objectives, theories of cognition and scientific method, respectively. However, all would agree that it is an aspect of scientific thinking rather than scientific knowledge, and that it is a most important ability to pass on to students. Most modern science curricula will make some recommendation about including it but how to teach it and how to assess it is far from clear.

One of the most profitable approaches for dealing with problem solving seems to have been that encouraged by Tamir (1982, 1985) while researching into enquiry skills in biology. The conclusion reached by Tamir and his group is that the practical mode has many unique features which distinguish it from what they term the analytical mode or constructive mode. Embedded in the practical mode, at its most mature level of development, is the notion of problem solving. The Israeli group have spent considerable energy developing experimental settings (e.g. the potato experiment, the carrot experiment) which capture the essence of problem solving in biology. Student performance on the experiments were assessed using a Practical Test Assessment Inventory (PTAI) which affords a template for assessing the full range of outcomes for the practical mode. The importance of this inventory approach, which on first inspection would seem to be unnecessarily cumbersome, is that it allows for the development of sound assessment procedures and also creates a common meta - language for teachers, enabling them to engage in meaningful dialogue about issues such as problem solving.

The aspect of problem solving emphasised in the video exercise concentrates on thinking style and the Predict/Observe/Interpret framework as it applies to a new situation.

It should be noted that the experiment did not appear "out of the blue" and what is described, subsequently, is related to the beginnings of inventories and intermediate skill coding which are being discussed and investigated by science teachers in this region.

Rationale for a Video Pratical, and its Production

There is a serious problem related to the isolation of problem solving for assessment purposes in that studies have shown that students' perception of the outcomes of a practical exercise can differ markedly from those of the teacher/designer. Students tend to see many exercises intended to be centered on problem solving as being much more to do with manipulative skills (Lynch, 1983).

The explanation is almost certainly due to the fact that "inexperienced" students really are battling with manipulative skills to an extent not anticipated by the designer and this is sufficient to swamp, in many cases, considerations related to "scientific thinking". The students thinking is taken up with the technical requirements of the exercise (Johnstone 1982). For that reason, we feel there could be real advantages in isolating problem solving issues, from time to time, in the form of a video practical.

The video practical that was used in this study was produced by one lecturer and two Dip.Ed. Students, and took approximately three person-days of work to produce the final edited 15 minute version that was used for examination purposes. The product was deemed to be perfectly adequate in all respects by the teachers and students involved in the examination. Neither the lecturer nor the Dip. Ed. Students had any special expertise in video production which does suggest that the technical production of video practicals by "non-experts" does not constitute a major hurdle.

METHODS

The Student sample and their Teachers

The video practical examination was given to four different classes of chemistry students (n=10, n=19, n=13, n=13). Each class was taken by an experienced chemistry teacher. The students had almost completed chemistry B which is the second year of HSC chemistry in Tasmania (chemistry A being the first year) and is usually only undertaken by the more able and more chemically oriented HSC students. Thus, the students contribute something of an elite group. The four teachers were all very experienced chemistry teachers with chemistry majors and had volunteered to take part in the trial.

Neither the teachers nor the students were familiar with the procedure of the video practical nor its Prediction/Observation/Interpretation structure. Neither were they familiar with the experiment itself. Consequently, students could not respond to the questions set from prior knowledge of outcomes which is most important in an exercise of this sort - it must be a new experience.

The Video Practical Examination: The Iron Wool/Acetic Acid Experiment

The experiment involves the reaction between glacial acetic acid and iron wool. The iron wool is soaked in glacial acetic and then introduced into a large round-bottomed flask, as shown in Figure 1, on the video. Students are shown the reactants and their introduction into the apparatus. The video is stopped and they are then asked to PREDICT what will take place.

After completion of this task the video is restarted and a stop clock introduced into the sequence. Students are then required to OBSERVE and RECORD THEIR OBSERVATIONS until the end of the reaction. After completion of the video and the second task they are then required to INTERPRET their observations in the light of their original predictions.

In the full practical this was the first half of the examination. The second half was hands-on experiment.

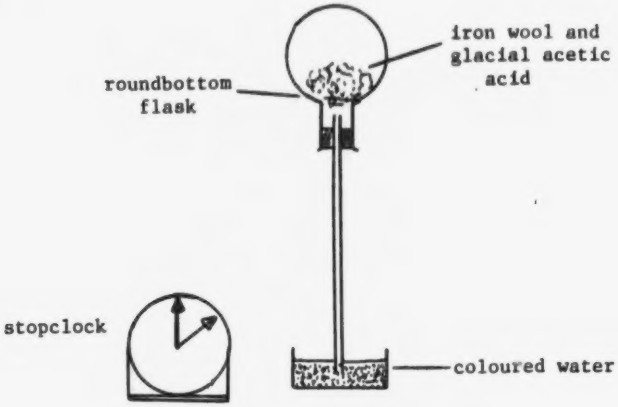

Figure 1. Set up for the iron wool/acetic acid experiment

Teachers and Students Attitudes to the Video Practical

Prior surveys of teachers' attitudes to modes of assessment revealed considerable lack of sympathy towards a formal examination of practical work. Those teachers who remembered the practical examination of almost two decades ago did so with less than affection (Lynch and Hargraves 1987).

The four teachers who conducted and marked the video-practical were asked, using a questionnaire, to assess how easy it was to identify the objectives and assess the students, and how useful it was as a practical tool. These responses are of considerable interest in relation to all aspects of usability. It should also be remembered that none of the teachers were involved in the production of the video.

Teachers Responses (n=4)

How easy was it to identify the objectives listed?

V. Easy	Easy	Some Difficulty	Great Difficulty
2	2	—	—

How easy was it to give students an assessment based on the objectives?

V. Easy	Easy	Some Difficulty	Great Difficulty
—	4	—	—

How do you rate the value of the practical exercises as an assessment tool?

	Excellent	V. Good	Good	Fair	Poor
Video Pract	3	1	—	—	—
Hands on component	—	4	—	—	—

After completion of the examination the students were asked to assess the experience in terms of "interest", "level of difficulty" and "fairness for assessment". It should be remembered that we had no idea what to expect from the student response and were somewhat anxious in view of the known general lack of enthusiasm for formal examinations. The student responses are summarized below.

Student Responses. (n=55)

Interest?

V. Interesting	Interesting	Not Part. Interesting	Un-interesting	V. Un-interesting
5	32	17	—	—

Level of Difficulty?

V. Difficult	Difficult	About Right	Easy	Too Easy
3	28	23	1	—

Fairness for assessment purposes?

V. Fair	Fair	Neutral	Unfair	Very Fair
2	24	19	9	1

What is most striking is the general lack of negative responses on the part of the students. The majority of students were positive about the examination in terms of "interest", "difficulty" and "fairness" (more marginal). Those students who considered it unfair as an assessment procedure (n=10) were troubled by their lack of familiarity with the procedures.

Student Performance Data: Average Marks

Average marks for each of the four classes are provided in Table 1 for the marking categories prediction/observation/interpretation.

Table 1. Average marks obtained by the students on the Video Practical Examination.

MARKING CATEGORIES and MARK AVERAGES			
HSC Student	Prediction (Max=10)	Observation (Max=5)	Interpretation (Max=10)
Group A (n=10)	5.2	3.6	5.1
Group B (n=19)	5.3	3.6	6.1
Group C (n=13)	4.9	3.6	3.6
Group D (n=13)	5.7	3.5	4.5

As can be seen there is consistency between groups in relation to marks received for "observation"; some inconsistency for "prediction" but more so for "interpretation".

Student Performance Data: Cross Correlations

The complete practical examination consisted of seven questions aimed at assessing seven different outcomes. The video practical component addressed the first three outcomes; prediction, observation and interpretation. For completeness, it would seem useful to present the totel correlation matrix (Table 2) which includes the correlation coefficient for each question with the overall practical mark and with the chemistry theory mark obtained by the student at the end of the year.

Table 2. Correlation Matrix for all seven outcomes, including overall practical and overall theory marks

	Predict Q.1	Observe Q.2	Interp Q.3	Plan Q.4	Observ Q.5	Calc Q.6	Manip Q7	Overall Pract	Chem Theory
Q.1 Predict	-	0.13	0.38	0.02	0.01	0.37	0.00	0.52	0.22
Q2 Observe		-	0.14	0.04	-0.03	0.01	-0.09	0.14	0.23
Q3 Interp			-	0.36	-0.27	0.15	-0.19	0.48	0.38
Q4 Plan				-	0.07	0.08	0.19	0.60	0.43
Q5 Observe					-	0.18	0.74	0.44	0.06
Q6 Calc.						-	0.13	0.66	0.26
Q7 Manip.							-	0.47	0.24
Overall Pract.									0.48

N=55

As far as the video practical is concerned (Q1, Q2, Q3) there would appear to be a low correlation (0.38) between prediction and interpretation and virtually no correlation for either (0.13, 0.14) with observation. There is virtually no correlation of observation (0.14) with the overall practical mark and this is strikingly different to the coefficients observed for the other six outcomes.

Conclusions and Implications for Teaching

It would seem appropriate to address these issues under the headings of usability, validity and reliability.

Usability of the Video Practical Examination

The action research aspect of this study reveals that it is easy enough to run a practical examination, and one that includes a video exercise. Teachers did not feel threatened by the task and were able to identify the objectives and assess them with ease. They were enthusiastic about the examination as a whole and particularly about the video exercise. The novelty of the video exercise and the problem solving framework used generated considerable debate afterwards between teachers and between students, which went far beyond the usual parameters of assessment. We would suggest that all the issues in the four guidelines listed were raised and probed by the exercise so that there were strong overtones of evaluation in the dialogue that ensued. The extent of this debate was considered to be an unexpected bonus. Perhaps equally surprising and heartening was the extent to which the students responded positively to the exercise. They are, of course, an elite group and clearly their ability to respond to the educational implications of the exercise should not be underestimated. It would also seem that they are well aware of the lack of objectivity of previous procedures.

Validity of the Video Practical Examination

At this stage we are still exploring the validity of the constructs that we are measuring, and the retrospective analysis of the performance data is useful in that regard. Behind the assessment procedures is, of course, a loosely constructed inventory in which empiricism is deliberately linked to educational outcomes, (see Lynch 1987). We would hope to formalize this into an inventory like PTAI but only when the teaching body feel that this is the appropriate step to take. What is of interest is that the framework that seems to be emerging is somewhat different for chemistry to that for biology. No doubt this reflects differences between the underlying deep structures of chemistry and biology as experimental sciences.

The lack of correlation between items raises questions as to whether this is a consequence of current teaching style or due to some fundamental difference in construct. This is particularly pertinent in relation to "observation" which is so central to the notion of "argument from evidence" and any emphasis on empiricism.

There is something of a dilemma in relation to these findings in that although a lack of correlation can perhaps be taken as evidence for the uniqueness of the construct, if the construct is now absorbed into the total mark then clearly it will change rank ordering to some extent at least, depending on its weighting. We do not see this as an invalid procedure but rather a consequence of redefining what should be assessed as an overall measure of student performance. Once again we should stress that the changes in assessment profile envisaged are not intended to be cosmetic. At their deepest level, the intention is to re-establish the priority of empiricism in pre-university teaching. It is not surprising to find that such a shift in teaching emphasis would require a substantial shift in the assessment profile. Factor analysis, in relation to construct independence should provide some insights and this line of enquiry is being pursued.

Reliability of the Video Practical Examination

Group sizes are small but some measure of reliability in the absence of the test/retest data can be gauged from the consistency between the average marks (see Table 1). A further indication of reliability was obtained from Cronbach Coefficients: Q=0.55; Q=0.56; Q=0.54. These are relatively low but not intolerable and should be seen in relation to the external theory coefficient of 0.60. In other words, the values are very close to that pertaining to the current external theory examination, though there is need for improvement. However, in the next phase of the study some attempts will be made to use different marker observers at different phases of the experimental program. Added to this is the need to establish procedures for dealing with reliability issues associated with progressive marks obtained from students, and the relative reliability of marks obtained at different stages of the student's development. We would hope that a more formal inventory will provide benefits in this regard.

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WHAT'S IN A SOLUTION? A LOOK AT LOGIC AND BELIEF IN PROBLEM SOLVING.

Jack A. Rowell and Chris J. Dawson

INTRODUCTION

In earlier work on problem solving we looked at the ability of individuals to control variables in problems requiring design and in those requiring the interpretation of secondhand experimental data (Rowell and Dawson, 1984). Subsequently we extended that work (Dawson and Rowell, 1987), concentrating on interpretation type problems which, as Kuhn and Brannock (1977) argued, are more valid in the school situation, and in life in general, in that students are rarely required to design controlled experiments but are frequently called upon to interpret data - which may not have been collected under controlled conditions.

The investigation to be reported here is a further extension of these problem solving studies. In general, we have sought to link our work on problem solving with related ideas in cognitive psychology on types of reasoning - reasoning based on a logical system of some kind, and on prior knowledge or beliefs (see, for example, Rosch 1983; Nisbett and Ross, 1980; Evans, Barston and Pollard, 1983; Evans, 1984; Revlin and Leirer, 1978; Revlin, Leirer, Yopp and Yopp, 1980). In particular, the aspect of our study reported here addresses belief bias in reasoning, which Evans defines (Evans et al. 1983, p. 295) as "The claim ... that when presented with deductive arguments to evaluate, subjects will make judgements upon a priori beliefs rather than on the basis of logical argument. Specifically they will tend to endorse arguments whose conclusions they believe and reject arguments whose conclusions they disbelieve, irrespective of their actual validity." The work of Evans expands and supports that of several other contributors to the field (see Evans et al. 1983, p. 295 for comprehensive references) who, to varying degrees, have demonstrated such an effect in syllogistic reasoning. Our study examines the possibility that the same effect operates also in relation to the interpretive problem solving situations used in our studies which involve inductive rather than deductive processes. As we come to know more about how people reason in general, and also in relation to particular content, so we shall be in a better position, as teachers, to help them to modify those processes should that be deemed advisable or desirable.

Experimental

1 Materials

Problems used in the experiment were exclusively of the interpretation kind, for reasons already given, and concerned either the time of oscillation of pendulums, or the smoking behavior of students. A sample pendulum question is set out in Figure 1. Smoking problems had precisely the same format and structure.

FIGURE 1

Although I'm not always very good at experimental work, I have been trying to look at the effect of three factors which may be related to the period of a pendulum (i.e. the time taken for a full swing). The factors I studied were the length of the string, the weight of the bob (the piece of metal on the end) and the material used to make the string (cotton or nylon).

QUESTION 1
From whatever knowledge of pendulums you have, which factor or factors (length, weight, type of string) do you expect to affect the time of swing? (You can say none of them)

I recently did experiments on four pendulums and got the results shown:

Experiment 1		Experiment 2	
Length of string	25 cm	Length of string	100 cm
Weight of bob	100 g	Weight of bob	50 g
Type of string	cotton	Type of string	cotton
PERIOD = 1 sec		PERIOD = 2 sec	

Experiment 3		Experiment 4	
Length of string	25 cm	Length of string	100 cm
Weight of bob	50 g	Weight of bob	100 g
Type of string	nylon	Type of string	nylon
PERIOD = 1 sec		PERIOD = 2 sec	

My next experiment will be to set up another pendulum under the following conditions:

Length of string	100 cm
Weight of bob	100 g
Type of string	cotton

I PREDICT THAT THE PERIOD OF THIS PENDULUM WILL BE 2 SEC and I want you to comment on this prediction by answering two more questions.

****
IN THESE QUESTIONS YOU WILL NEED TO USE ALL THE DATA COLLECTED IN THE FOUR EXPERIMENTS ABOVE TO HELP YOU GET A GOOD ANSWER.
****

QUESTION 2
I predicted 2 sec for the period because I worked out that the four experiments above showed that the length of the string is related to the period, but the weight of the bob and the type of string are not. Say in as much detail as you can whether you think I have

worked correctly from the results I got in the four experiments. Start your answer with "Yes, because......." OR "No, because........".

Each problem was concerned with the possible effect of three factors on the relevant dependent variable: length of string, weight of the bob, and type of string, on the time of oscillation of a pendulum; whether the students are fitness fanatics, whether their parents smoke, and their favourite colour, on student smoking behaviour. As will be evident, one factor in the physical problem (type of string) and one in the social problem (colour preference) were, intentionally, as obviously irrelevant as we could make them. Our intention was that students should judge any outcome based on these factors as unbelievable. On the other hand, length of string, and whether a student was a fitness fanatic were intended to be highly believable factors. Question 1 in each problem (see Figure 1) was used to assess the extent to which this view was justified.

Four versions of each of the two problems were prepared. In version 1, illustrated by the pendulum problem in Figure 1, the prediction was valid (followed logically from the data provided) and was believable. In 2, the prediction was valid but unbelievable. In 3, it was invalid (did not follow logically from the data provided) but was believable. And in 4 it was both invalid and unbelievable. The corresponding versions of the social problem were numbered 5 to 8 repectively. For the pendulum experiment, length of the string was the predicted influential variable for both believable problem versions (in the invalid one, of course, it did not follow logically from the "experimental" data provided). Nature of the string was the predicted influential variable for the two unbelievable versions. For the smoking problem, fitness fanaticism and colour preference were the predicted influential variables for the believable versions respectively.

Thirty two different permutations of the four versions of the physical and social problems were produced, each containing one physical and one social problem. Thus 1 was paired with 5, 6, 7, 8; 2 with 5, 6, 7, 8 and so on, and each pairing was prepared in both orders; that is (1, 5), (5, 1) for example.

In an attempt to minimise the possible occurrence of belief bias, hence to demonstrate its realness should it be found, attention was drawn as strongly as possible to the need to use the data collected (see Figure 1).

2 Subjects

Requests sent to individual schools asking for their cooperation resulted in using fifteen of them, representing both state and independent systems. These schools provided a total of 701 Year 11 subjects for the experiment.

3 Test Administration

Testing was carried out by the authors and by an experienced research assistant. All testing was carried out in the schools either in a classroom or a laboratory. Students were told that they were going to take a short problem solving test which was important as its results would be used to help us, and later, their teachers and them, to understand some difficulties in thinking and reasoning. Assignment of the 32 different test forms to students was random. Approximately 30 minutes were allowed for test completion, which proved adequate for all students, and this was usually followed by a short talk explaining the test more fully and answering questions, as time permitted.

4 Scoring

The nature of the scoring system was simple categorisation. For example; agreement or disagreement with the prediction; did the student use the data, prior knowledge or both; did the student justify his/her agreement/disagreement by the use of conjunctive or disjunctive argument or both? The authors established the categorization system to be followed, and the scoring was done independently by a research assistant.

RESULTS AND ANALYSIS

Before examining the experimental data and judging the prediction made, all students were asked to say, from whatever knowledge they had of the situation, whether they expected each of the three factors to affect the dependent variable in the problem being considered (see Question 1 of Figure 1). The results for both the pendulum and smoking problems are recorded in Table 1.

TABLE 1
Prior Expectation of students

PROBLEM	FACTOR	Expectation of effect		
		Yes	No	Unsure
PENDULUM	Length	563 (83.8)	106 (15.8)	3 (0.3)
	Weight	474 (70.5)	195 (29.0)	3 (0.3)
	Type of String	134 (20.0)	527 (78.5)	10 (1.5)
SMOKING	Fitness Fanaticism	330 (48.7)	338 (49.9)	10 (1.5)
	Parents Smoke	389 (57.4)	273 (40.3)	16 (2.4)
	Colour Preference	22 (3.2)	651 (96.2)	4 (0.6)

Figures in brackets are percentages of non missing responses

From Table 1, it is apparent that the physical and social problems differed markedly in terms of the expectations students attached to the three factors. Length (pendulum) was a more believable agent affecting time of swing than fitness fanaticism was in affecting smoking behaviour. Further, an effect on smoking behaviour of colour preference was considered more unbelievable than a corresponding effect of type of string on time of swing.

Question 2 of each problem situation commenced with a statement of the prediction purportedly made from the experimental data and asked students, in essence, whether they accepted it or not, and to comment on the reasons given (see Figure 1). We shall not consider their explanations here but will confine ourselves to their acceptance/rejection of the predictions made. The relevant data are recorded in Table 2.

TABLE 2
Number of students accepting a prediction
(Total response number for each group is in brackets)

PROBLEM	Validity of Prediction	Believability of prediction	
		Believable	Not Believable
	Valid	101	79
PENDULUM		(154)	(171)
	Invalid	30	26
		(163)	(166)
	Valid	129	79
SMOKING		(174)	(165)
	Invalid	34	9
		(159)	(169)

Note: The between group variability in total responses is due to slightly unequal distribution of problems among the students and to some missing data.

From Table 2, acceptance/rejection data were analyzed separately for the physical (pendulum) and social (smoking) problems, testing four directional hypotheses:

H_1: Believable predictions will be accepted and unbelievable ones rejected irrespective of their validity.

H_2: Valid predictions will be accepted and invalid ones rejected irrespective of the believability.

H_3: For unbelievable predictions, more correct (i.e. rationally derived from the data) answers will be given to invalid than valid predictions.

H_4: For believable predictions, more correct answers will be given to valid than invalid predictions.

H_3 and H_4 are separate aspects of a more general hypothesis that there will be more correct responses when logic and belief are in accord than when the two conflict. However, their separate testing is required since, as discussed later, the results have a potentially important connection with the issue of learning and prior knowledge.

H_1 is the belief bias hypothesis. Analogously, H_2 might be called a validity bias hypothesis. In essence it is a statement that Year 11 students are logical in their reasoning.

The data from Table 2 consist of frequencies in discrete categories obtained from independent groups of students. Testing of the four directional hypotheses, therefore, was carried out using chi square, corrected for continuity (Siegel, 1956, p. 107), together with 1-tailed probability tests. In each case the number of degrees of freedom is 1 (2 x 2 tables). Results are recorded in Table 3.

TABLE 3
Values of chi square associated with tests of
directional hypotheses H_1 - H_4

Problem	Directional Hypotheses			
Content	H_1	H_2	H_3	H_4
PENDULUM	0.36	8.84**	3.85*	0.39
SMOKING	2.73*	14.55**	6.83**	0.01

*$p < .05$ **$p < .01$ (1-tailed) df=1

From Table 3 it is apparent that a belief bias exists in relation to the social science but not the physical science problem (H_1). As anticipated, more valid predictions were accepted and invalid ones rejected in both content areas (H_2). Of particular interest, however, there was an asymmetry of results, which held across content areas, in relation to the general hypothesis that more correct responses will occur when logic accords with belief than when the two are in conflict. For both problem contents, although the general hypothesis appeared to hold (physical, a/ 75.3% correct when logic accords with belief, b/ 63.5% correct when logic and belief conflict; social, 84.3% correct in condition a/, 63.0% correct in condition b/), the difference in frequency of correct responses was almost entirely attributable to responses to the unbelievable predictions (Table 3).

DISCUSSION

The issue of the relation between knowledge and logic in reasoning is both important and controversial. In the past decade, different authors have proposed different explanatory models, and have supported these with the results of experimental studies. Thus, for example, Revlin and his colleagues (Revlin and Leirer, 1978; Revlin et al., 1980) have proposed an essentially rational model of reasoning wherein evidence of belief bias is explained via encoding errors, and a dominant tendency to choose a response that no conclusion is possible. Evans and his colleagues (Evans et al., 1983; Evans, 1984) have criticised the Revlin model and proposed a dual process theory in which preconscious heuristic processes first judge the relevance of features of the problem, and select what it is that the subjects are reasoning about. Analytic processes then take over "... to show the logical consequences of decisions already taken" (Evans, 1984, p. 461). The relevant empirical work of Evans (Evans et al., 1983) strongly supports the existence of belief bias in syllogistic reasoning which, Evans (1984, p. 462) claims, operates through the heuristc system.

The investigation reported here extends the ambit of the knowledge/logic relationship in reasoning from studies using syllogisms to broader questions of rational competence in more real life situations, especially as they might occur in the classroom, involving inductive rather than deductive processes and both physical and social scientific content. Nevertheless, while recognizing these considerable changes, our results strongly support the effect of the logical validity of a conclusion (in our case, prediction from experimental data) on the likelihood of its acceptance, and in this we are in accord with both Revlin and Evans. However, the evidence for operation of a belief bias in our data is much weaker that in Evans' studies of syllogistic reasoning, particularly, and is limited to social scientific content.

At first sight the possible relative immunity from belief bias of inductive reasoning in scientific problems, assuming our pendulum problem is representative of them, coupled with the evident effect of logical validity on the acceptance of predictions, paints a rosy picture of Year 11 reasoning in the science classroom. The matter is more complicated, however. As Revlin and Evans found for syllogistic reasoning, we also found that when there was a potential for inductive processes to be engaged there was a difference in percentage of correct answers depending on whether belief accorded with logic or was in conflict with it. Our figures (see the Results section) were, for the pendulum problem, 75.3% and 63.5%; and for the smoking problem, 84.3% and 63.0% respectively - closely similar to Revlin's figures for syllogistic reasoning (Revlin et al., 1980, p. 589), but not showing as great a distinction as those of Evans (Evans et al., 1983, pp. 298, 300, and 302). Of further importance to our developing argument is an asymmetry in the results of the conflict between logic and believability which, despite the absence of any belief bias as a general effect, does highlight an important aspect of prior belief. What was found was that, although for believable outcomes the frequencies of acceptance (correct response) of valid predictions and rejection of invalid ones (correct response) were closely similar, the same relation was not true for unbelievable predictions in both physical and social problems (see hypotheses H3 and H4 and their tests in Table 3. See also Evans et al., 1983, p. 302). Unbelievable predictions were more likely to be rejected (correct response) in problems where they did not follow logically from the data than accepted (correct response) where they did.

The importance of these general and specific results concerning belief and logic is that they forge a link between sudies of the psychology of reasoning and those concerned with learning, development and instruction. In science education it has become commonplace to insist that the importance of prior knowledge should be taken into account in our teaching strategies. Studies of reasoning support this. The evidence across studies is that students are more likely to be correct if logic and belief are in accord rather than in conflict. It is in relation to strategies designed to change misconceptions, however, that studies of reasoning may have their greatest impact on instruction, differentially supporting some rather than others. In essence, the argument from our results is this: when students find a conclusion unbelievable (presumably because it conflicts with prior spontaneous beliefs/knowledge) they will not readily accept it even though it follows logically from an empirical base. Even for those who do verbally acquiesce to the logic of the situation, of course there is no guarantee that such acceptance will correspond with subsequent action, at least in the short term (see, for example Rowell and Dawson, 1983). Rather than tackling the problem "head on" and attempting in direct fashion to make the unbelievable believable by the force of rationality, reasoning data indicate it is better to work from the believable, however indirect that may initially appear. This is generally possible because most people do not have a single coherent basis for understanding a concept in the early stages of its construction (see, for example, Inhelder Sinclair and Bovet, 1974; Di Sessa, 1982). An alternative is to construct new knowledge, and belief, on the basis of the old. In that way the previously unbelievable becomes believable, and only when that has occurred does the teacher bring the new beliefs into conflict with the old in a situation where the student is better able to make an unbiased, rational decision (see Rowell and Dawson, 1985).

Our next steps will be to examine in depth the bases on which individual students' acceptance and rejection of predictions have been made, in order to reflect on the respective merits of the models of reasoning proposed by Revlin and Evans.

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J.D. BERNAL AND SCIENCE EDUCATION : A TRIBUTE TO THE 50TH ANNIVERSARY OF THE PUBLICATION OF "THE SOCIAL FUNCTION OF SCIENCE"

R.T. Cross & R.F. Price.

INTRODUCTION

We offer this tribute to Desmond Bernal on three grounds: in recognition of his special contribution to the ever-increasingly important question of "The Social Function of Science"; as an argument for the study of the biography of scientists and the history of science; and because his major writings remain informative and inspirational for readers today.

Bernal The Man

Born in Ireland on the 10th May 1901, Bernal went to Stonyhurst and Bedford schools before entering Cambridge as an undergraduate in 1919. This was, as C.P. Snow observed, the beginning of one of the great intellectual periods at that university (Snow, 1964). In 1922 he began work as a crystallographer under Sir William Bragg in the Davy-Faraday laboratory at the Royal Institution in London.

Bernal's contribution to science ranged from X-Ray analysis leading to elucidation of the molecular structure of the sex hormones, oestrone and oestriol (work which Zukerman believed should have won him the Nobel Prize), through the study of the structure of liquids, to speculations on the origin and nature of life (1963). Ironically, it was during World War 2, as scientific advisor to the Lord Louis Mountbatten, Chief of Combined Operations, that Bernal came nearest to fulfilling his dream of science in the service of society! In that capacity he worked on the results of bombing cities, and made a special contribution to the Allied landing in France by his work on the floating harbour, Mulberry.

Bernal was a marxist and a believer in the need to defend the USSR in the period of the Cold War. He was impressed by the attention given to science by the Soviet government and this led him into regrettable statements at the time of "the Lysenko controversy" (Goldsmith, 1980, 189-97). His association with the British Communist Party, membership of which lasted from his student days to about 1933, was also damaging to his influence on the politics of science.

C.P. Snow summed up Bernal as a scientist, saying:

> in natural gifts he stands very high; he is the most learned scientist of his time, the last of whom it will be said, with meaning that he knew science, he has enormous imaginative sweep and deep insight...(26)

Snow also commented on the incongruent nature of his choice of crystallography as his field of research, an area of study requiring painstaking measurement and a methodical approach. Seemingly deficient in these qualities, he was instead "wildly imaginative, sometimes making a disconcerting flight into fantasy" (Snow, 23)

From the early 1930s until his death in 1971 he spent much of his working life promoting his vision of "the social function of science" as described in his book written in 1938 (Bernal, 1939). This work led to his involvement with the Association of Scientific Workers. During the 30s this association became influential (Werskey, 1972). He was a founding member of the illfated World Federation of Scientific Workers (a body which helped bring about the first Pugwash meeting in 1957) and the World Peace Congress, of which he finally became President. One of his contributions to the last cause was his book World Without War (1958), a work which though dated and often personal, can still serve as a useful guide to ways of considering this question.

BERNAL AND THE SOCIAL FUNCTION OF SCIENCE

The sweep of Bernal's grasp is shown by a cursory glance at some of the headings in his book: History: Science, Learning and Craft; The Birth of Modern Science; Science and Socialism; Science in Education; The Efficiency of Scientific Research; Science and War; Scientific Communication; Science in the Service of Man; Science and Social Transformation. One has to remind oneself, this was 1939! However, Nature had already published in a now famous supplement in 1938 entitled "The Social Relations of Science", in which Bernal had written, prophetically:

> Science as a factor in modern society is uncontrolled; what it does and does not do is left largely to chance and to the operations of ill-understood factors. If we are to prevent it becoming uncontrollable and destructive of the very civilization it has built up, we must begin at least to understand how science and society interact (Nature, 1938, 736).

The supplement, contributors to which included such famous names as Bragg, Wells, Ginsberg, Bartlett, Haldane, Huxley, Tizard, Blackett and Needham, advocated the establishment of a society to study the social relations of science.

Throughout his life Bernal remained an enthusiast for the positive role science could play in a rationally organised society. He amplified some of his ideas on this theme in the collection of essays published as The Freedom of Necessity in 1949. The title refers back to Hegel and Engels, to the idea that "freedom is to be measured by knowledge", as Bernal phrased it (2). Bernal argued that the function of science was not only to provide the essentials for a healthy life for all, but was to be involved in providing the means by which humans could lead ever more satisfying lives through the arts in a world of peace. He had already, in 1938, argued that for this to occur science needed to be consciously organised, and the complex interrelations of science and society must be understood.

Bernal's comments on the scientific worker of 1938 evoke parallels and differences. He notes their economic dependency, their personal livelihood depending on pleasing their employer. This he saw as leading to conflicts of interest and an emasculation of the traditional functioning of science. In addition there was the frustration of working for antisocial, rather than socially useful, purposes, especially working for war. Bernal, surrounded by many like-minded colleagues, optimistically predicted that scientists would not just feel a sense of frustration about this, but would revolt against this situation. Regretably, this revolt has yet to come! For many the exacerbation of the conditions against which Bernal spoke has led instead to an abandonment of science. For others the tendency to conform, about which Bernal also wrote (1939, 388), still exerts great power.

As has been indicated above, Bernal was, already in the thirties and forties, not a lone voice, although his was probably the clearest. Goldsmith (op.cit) makes the point that The Social Function of Science represented the views of the social responsibility movement of the time and that this constituted an "Invisible College" of people who were determined to "bring it into the market place" (1966, p.9). The extent of his influence on his contemporaries can be judged by the contributing authors to the Science of Science (Goldsmith and Mackay (eds.), 1964), a collection of writings celebrating the 25th anniversary of the publication of The Social Function of Science. They included Kapitsa, Snow, Blackett, Needham and Haldane.

However, conservatives mounted vitriolic attacks on The Social Function of Science in the press. Baker (1939), an Oxford Biologist wrote the "Counterblast to Bernalism". In this remarkable attack Baker refers to "gangs of scientists being told what to discover and Bernalists stifling discovery. Let the gangsters work always in gangs ... Let there be freedom, nevertheless, for those who lack the gang instinct..." Bernal's reply was marvellously restrained addressing the issues:

> It would be a sheer waste of time and ink to attempt to continue a controversy on Dr. Baker's terms. But the issue itself is real enough, although it cannot be seriously discussed till the caricature of it is cleared away. What science is for and how it can best be carried on, are vital questions to discuss and act on. The first question has really two distinct parts, according to whether we consider science as a social activity, part of the general complex of such activities, or as the personal interests of an individual. — No question arises as to whether or not science should be used for social ends. It is being used for Social ends, — and largely for bad ends. Now

> what ultimate ends do we set for science? They are the old indissoluble human trinity, goodness, truth and beauty (Bernal, 1939b).

In 1940 a group of conservatives formed the "Society for Freedom in Science" to combat what they saw as the threat to freedom in science. The most influential among this group was Polanyi (Wood, 1959). And after the war they received the blessing of "Nature" and an editorial was mildly supportive of them (Editorial, Nature, 1946). In the same issue Baker and Tansley (1946) vilify the social responsibility movement by linking the planning of science to science in the USSR. In The Social Function of Science Bernal advocates the planning of science, the reorganization of research, scientific communications, the finance of science, and strategy of scientific advance so that science can work for the service of all.

Perhaps the most significant sections of The Social Function are those which relate to such topics as:-

The Possibilities that Science Offers;

1. Science affects productive methods and this has a far reaching impact on society. The force the scientists exert is blind they have no knowledge of the social, economic and political consequences of their work.
2. Consciousness of frustration, here we see Bernal surrounded by many like-minded colleagues optimistically predicting that scientists would not just feel a sense of frustration about the development of the science of destruction instead of for the benefit of mankind but would revolt against this situation.

The Scientist as a Worker;

1. Economic Dependency, personal livelihood depends on pleasing the employer this leads to conflicts of interest and an emasclation of the traditional functioning of science.
2. The tendency to conform. Scientists by the selection and educational processes tend to conform and this means conforming to the prevailing middle class value systems. This has enormous consequences for the sort of research and the nature of the findings.

The Scientists as a Citizen;

Here Bernal ranges widely concerned himself with the preparations for war, facism, marxism and the 5 year plan in the USSR.

Social Consciousness;

The depth of his understanding of the social consequences of the changed nature of scientific work during the 1930s is vividly spelt out.

SCIENCE IN SCHOOLS

Bernal was deeply concerned with the state of science education in the 1930s. His criticisms have been echoed down the decades by others but his suggestions for change still have a freshness that demands attention. In 1938 he wrote:

> The pioneers of the teaching of science imagined that its introduction into education would remove the conventionality, artificiality, and backward-lookingness which were characteristic of classical studies, but they were gravely disappointed... The professional schoolmaster ... almost managed to make the understanding of chemical reactions as dull and dogmatic an affair as the reading of Virgil's Aeneid. The chief claim for the use of science education is that it teaches a child something about the actual universe in which he is living, ...at the same time teaches him how to think logically and inductively by studying scientific method. A certain limited success has been reached in the first of these aims, but practically none at all in the method ... The way in which educated people respond to such quackeries as spiritualism or astrology, not to say more dangerous ones such as racial theories or currency myths, shows that fifty years of education in the method of science in Britain or Germany has produced no visible effect whatever (1939, 72).

Bernal devotes fifteen pages of The Social Function to "Changing the Teaching of Science", dealing with secondary and tertiary level schools and details of the curriculum. Like Armstrong before him, he advocates introducing an element of discovery into science teaching, thus predating the discovery learning movement, and once again showing how ideas repeat themselves in education as in other history. It is significant today that he argued then for the inclusion of questions of social responsibility in the teaching of science when he wrote:

> Throughout, the social implications of science, the powers that it puts into men's hands, the uses they could make them and those which they in fact do, should be brought out and made real by reference to immediate experience of ordinary life (246).

Also significant today is his call for teaching "science for all" (1939, 248 & 1949, 36), which would give the power to citizens through developing in them various abilities. These would include:

> "To see that everyone not only has a general picture of the world in terms of modern knowledge, but also appreciates and can use the type of argument on which that knowledge is based."
>
> To know where to turn when they have problems they cannot solve themselves; to know where science is to be found and to understand enough to see its general bearing.
>
> To be able to safeguard themselves from "anti-rational tendencies which are otherwise at the command of all reactionary forces".

> To provide enough understanding of the place of science in society to enable the great majority that will not be actively engaged in scientific pursuits to collaborate intelligently with those who are, and to be able to criticise or appreciate the effect of science on society.
>
> To give a practical understanding of scientific method, sufficient to be applicable to the problems which the citizen has to face in his individual and social life.

In making these suggestions Bernal was asking for radical changes in science teaching beyond the ability of teachers in his day, and not even easy to accomplish today, when so many more are moving in the direction he charted. Few now would quarrel with his demand that they should bring science teaching "more closely into relation with ordinary life". But as he argued in a paper originally published in the U.S. Science Education in 1939 and reprinted in The Freedom of Necessity in 1949, to do this they will have to take a larger part themselves in life including not just teaching about science but also "studying it as a means of helping to solve with the class some immediate and important social problem" (1949, 137). For Bernal science teachers, with their special knowledge, represented one of society's great resources, and it was important that this resource should be used for the benefit of society. That knowledge, he remarked, was "a possession which is being wasted if it is not being used". He appealed to teachers to accept their special responsibility and work actively for human betterment (1949, 138). At the same time he had no illusions. In addressing practical, and controversial social problems and in giving leadership to their students they would need to be tactful. Aware that "anti-scientific and anti-social forces are powerfully entrenched in the school system" he warned that the approach used by teachers must depend on circumstances. The essential was the teachers "should understand the situation and know what they were striving for" (1949, 143-44). He believed that if school teachers knew their job they would be able to convince the community that a rational approach to social problems is "neither radicalism nor idealistic philanthropy but plain common sense" (1946, 156). To sum up Bernal's position on science teaching in general education:

A new relation between the science teacher and his pupils and between both of these and the community are necessary (1949, 142).

and

Science and education are still powerful weapons for the defence of democracy, and for making possible the extension and development of democracy in the direction of an ordered, yet free, co-operative community (ibid. 158).

Bernal on the Method of Science

Already in 1929 Bernal had commented on the dual aspect of scientific theory: "inside science its function is to organise existing knowledge and point the way to the acquisition of new knowledge; outside science it is a form of statement about the nature of the universe." He warned that a confusion of these two aspects had done much harm to "the position of science in general culture" (reprinted 1949, 94). Almost three decades later, in that seminal work on Science in History he explored the origins and nature of modern science. There he remarked on the distinction between the scientific mode, which is indicative, "telling people how to do what they want to do"; and the artistic mode, "a mode which is equally social" and one which functions "to generate first the wish and then the will for special action" (1969, 41). Nicely, he comments; "Neither of these modes is complete without the other and, in fact, neither in science nor in art is one to be found without the other" (ibid). So much for notions of "value - free science"!

In 1940 Bernal wrote an essay welcoming the final appearance in English of Engels' Dialectics of Nature. Bernal saw dialectical materialism as a welcome correction to both mechanistic and emphiricist ideas in science. In Science in History (1954, reprinted 1969) Bernal again gives an account of dialectical materialism, but rather in the context of the social sciences, and it is rather the social function, the social responsibility of science to which he keeps returning. The development of a deeper exploration of the distinction of mechanistic versus dialectical understandings, of explanations in dialectical forms, has been left to such writers as Needham, exploring the relation between Chinese (dialectical/organic) and European science, or more recently, Rose, Lewontin and Kamin (1984, esp. ch 10).

CONCLUSION

Bernal worked tirelessly for the cause of socially responsible science. He felt that the progress of science was sufficient to alleviate the many problems that confront humankind. He believed that science should concern itself in a planned way to improving the lot of humankind (Ravetz, 1971, p. 312). He was hampered by being linked with the planned science of the USSR while Russia was suffering the worst of Stalin's excesses. He did irreparable harm to his cause by the constancy of this support for the Soviet methods of controlling scientific investigations. Certainly the Lysenko affair (Rose and Rose, 1976) was an Achilles heel; even as late as 1949 he was reviewing Lysenko's work in a favourable light (Bernal, 1949b). With the flux of time his grand design, which seemed so radical in the 30s and 40s now appears to be an essential part of the writings and conference papers which abound on the subject of science, technology and society. Curriculum developers and science education specialists could do worse than to adopt Bernal's blueprint for the establishment of science working for society's needs.

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CASE STUDIES OF STUDENT RESEARCH PROJECTS IN SCHOOL SCIENCE

Russell Tytler

INTRODUCTION

Independent research projects (IRP's) have been receiving increasing attention in recent years, both in a Science Fair context and within the formal school curriculum itself. As schools are struggling to make the necessary links between what is done internally and what goes on in the outside world, the IRP is emerging as a significant development in science education in Victoria as elsewhere.

Interest in this study relates to the requirements of motivation and autonomous behaviour the IRP places on the participant. The Research Project is unusual in that, within it, school students are assumed to be capable of acting to a large extent autonomously, in a manner generally associated with adults (see Boud [1981]). A preliminary questionnaire administered to 365 prizewinners in the Victorian Science Talent Search (STS) confirmed the reasonableness of this assumption by indicating that school did not figure as a very important factor either as a source of ideas for the projects or with help in their execution. While the questionnaire gave some interesting profiles of the opinions and aims of these students, it did not give much insight into their personal response to the work, or the variations in the way they approach these projects and come to terms with the myriads of problems and challenges met along the way. In order to probe deeper into the nature of the work involved, and the attitudes and competencies students bring to bear on it, a more personal approach was decided upon, using a personal interview technique to build up some case studies (Stenhouse 1978) as "instances" of autonomous behaviour.

The Student Interviews

A small number of schools in which STS had been a feature was targeted, and the teacher responsible for the running of STS within the school asked to recommend for interview up to four students who had entered the "Research" or "Models" section of the competition. The criteria for selection were that the students should have displayed sufficient commitment to the task to be able to talk about it meaningfully, and should be sufficiently articulate to be able to communicate effectively. They were not necessarily successful entrants, and in fact a number interviewed either received no award or a minor award.

Interviews were conducted in five schools. Four were city schools, and three of these were independent schools. In terms of STS entries, this would be a representative sample. Interviews involved both boys and girls from Year 5 up to Year 10.

During the interviews students were encouraged to tell, in their own words as much as possible, the "story" of their projects, rather than simply describe the results of their experiments. The focus of the study was the nature of these students' experiences of independent enquiry: how they see it, where their initiatives originate, their perceptions of the experience and how it relates to classwork, and their attitudes to learning.

The students

Below is listed the students interviewed and their projects:-

William (Yr 7):	A Model Hydroponic garden
Melissa (Yr 9):	Pulse and breathing rate, Antifreeze, Lathering
Brian (Yr. 10):	An Electronic Metronome
Stewart (Yr. 10):	Amino Acid sequences in Chicken Embryos
Jill (Yr. 10):	Digestive juices of carnivorous plants
John (Yr. 9):	A Model Plane with a special design feature
Warwick and Gavin (Yr. 8):	Hot Air Balloon
Phil (Yr. 10):	Ecological Study, Spiders, Fitness routines
Daniel (Yr. 6):	Electronic Door Alarm
Lachlan (Yr. 10):	Model car studies
Valda (Yr. 10):	Chlorine corrosion, Effect of chemicals on herbs
Hamish (Yr. 5):	Water clock
Matthew (Yr. 5):	Evolution model
Margaret (Yr. 8):	Accuracy of Weather Prediction
Linda (Yr. 8):	Sinking rate of a chicken bone
Sarah (Yr. 7):	Pet Rabbit study
Dale (Yr. 7):	Guinea pig studies
Mark (Yr. 7):	Growing wheat in different soil types

What types of students are these?

Despite the wide range of project types, and even of intellectual styles, exhibited by these students, there are two attributes that were in evidence in all cases, and stand out particularly in the more impressive of them. Firstly, there is the commitment to the pursuit and conclusion of a project, as evidenced in displays of enthusiasm and the sometimes extraordinary amount of time and effort involved, and secondly the independence shown in the pursuit of background knowledge and the arrangement of experimental procedures or design innovations.

In terms of the nature and extent of their commitment, these students could be categorized into three relatively distinct, but not exclusive camps.

1. The Genuinely Curious

There is a group of these students who stand out as showing an extraordinary amount of independence, drive and curiosity, and indeed have done so from an early age. This group was also interesting for the fact that they all had worked out a coherent philosophy dealing with their commitment to new knowledge, and seemed generally very aware of the fact that they were different from other students in regard to their curiosity and independent drive.

Melissa, for instance, arranged for entry into the competition herself, while still in primary school, and had a history even then of notebooks taken of chemistry experiments. Curiosity has become an important part of her self image.

> "That's the basis for all of my projects... questions you think up... I think anybody who's got an exploring mind thinks of questions on ... things that are around or that are happening to them that they think ... why is that happening... STS provides an outlet that you can go into ... and actually try to find the answers to those."

For William the drive is towards building things rather than finding out "why?". For him also, though, the notebooks and early interest in science and experiments. He referred to "this little book at home... it's an exercise book ... and every time I get an idea I scribble it down and make this plan..."

He talked about some of his other science projects:-

> "I've made a solar wind ... power plant, and a box with a mouse trained to jump up on this lever, which puts a light on, then run to its feed bowl and feed drops into it... and ... quite a few electronics experiments ... and experiments with heat. At the moment I'm trying to build a steam engine using an existing petrol engine."

Stewart's fierceness in his independence in study and the pursuit of knowledge was evident already in Grade 6, when his father suggested he extend his chicken breeding into a school project:-

> "Before that I'd actually been able to breed with chickens ... make crosses... make hybrids ... for my own interest. I'd never heard of anyone doing it. And ... couldn't hurt, just to see if you get a few more eggs."

And his attitude to received knowledge:

> "When you just do a practical, someone else has ... its just set down, in the curriculum... you just do that, its not.... really anything, but if you have to do it yourself it shows a bit more."

Phil had been working on IRP's since Year 7, as an extension of an enthusiasm that embraces a wide range of interests. He also has a strong attitude about the benefits of IRP's:

> "You can choose your own topic, and you find out things for yourself... you don't read it out of the book, and you learn it, and that's it. Instead you learn about something, and you learn it firsthand. Like in the lake ... water temperatures and the various insects that live in the lake... and the spiders, I learnt a lot more about spiders, and I learnt that firsthand... I mean actually experiencing and finding something that you didn't know before. Not reading it out of a book, which I consider to be secondhand. Someone's already written it down."

2. The Traditionalists

Another set of students were more conservative in their approach, and entered STS for the competition's sake, or possibly due to encouragement from parents.

These students, while valuing the choice and the independence offered by the STS project, seemed to regard the work as a straightforward extension of their normal science, and did not display either the drive nor that rather more radical philosophy based on independence and curiosity found with the "genuinely curious" group. They were nevertheless led by the competition into activities they would not have otherwise undertaken within their schooling, such as the design and planning of complex experiments and the searching of academic libraries for information. In some cases the project involved a significant extension of their normal activities. Brian was used to constructing electronics kits, but the STS led him for the first time into a design venture.

> "This is permanent ... it was the first one I had modified. ... I stayed up till midnight the night before it had to be handed in. I did enjoy it after all the effort I put in... and... well there it is ... a completed model and I could hand it in."

Mark and Sarah were encouraged by STS to use their pets for animal behaviour studies. Valda was a committed student, and the STS provided an outlet for her considerable drive and organizational skills, and a chance to build up points towards her aim of a career in science. Jill enrolled for a project-oriented science option out of a vague interest, but became significantly motivated by the discovery of microscopic organisms in the digestive juices of her carnivorous plants.

These students did not seem to have the same innate curiosity and motivation of the first group, but were, rather, led in to curiosity by the attractions of the activity itself.

3. The Hobbyists

Another group of students, all boys, exhibited that classic enthusiasm associated with the pursuit of construction hobbies. John and his family had a longstanding interest in constructing model aeroplanes, and used STS as a motivation to branch into an unusual and effective design modification. Lachlan had an interest in model cars, and during the project carried out detailed studies on the power and efficiency of various elastic propulsion designs. He was quite explicit about his "Project Science" class enabling him to extend his hobbies:

> "I'm sure every kid has a hobby ... and in this sort of class you can do almost all your hobbies. It's sort of an extension of your hobby and maybe expanding your horizons."

The girls had their own significant interests, of course, but it does seem that when it comes to the construction of models, the boys' background with construction hobbies offers an advantage. The models section of STS is in fact the only one in which boys predominate.

Male-Female Differences

No other significant differences in the way boys and girls approached the projects showed up during the interviews. There was no evidence of a lack of willingness to take risks on the part of the girls, an attribute said to distinguish between the sexes. Projects begun with no guarantee of a result were as characteristic of the girls as of the boys.

Melissa and Valda were as assured and confident in discussing their work as any of the boys, and while Jill presented as quiet and somewhat lacking in confidence, so did Matthew.

Nor was evidence found, within this set of interviews, of the currently favoured distinction between boys, who can pursue problems for their own sake, and girls, who take a wider social view of science and require human relevance for their project.

The project as a vehicle for knowledge acquisition

The question "What knowledge is worth having?" is central to the considerations of this study. It would most likely be generally accepted that the sorts of skills, realizations, attitudes and behaviours exhibited by these case studies are an essential component of what we hope to impart to students as part of a worthwhile education. Theoretic, disciplinary knowledge, the type contained in books, however, is also important, and it is worthwhile to look at the extent to which the IRP can act as a vehicle for the acquisition of knowledge of this type.

Stewart and Jill did more library work than any of the other students. Stewart didn't mention it until prompted, but in fact did an enormous amount of background research.

He was very aware of the extent to which he had learnt to use the library system, a skill he regarded as a step up from merely using set books.

> "You have to try and find different references and you can't just go to any book.. You learn more this way because you have to find out just a bit more ... along the way you find out a lot more information even if its just about amino acid sequences ... that type of thing, RNA how that's involved in making the protein... and that was just along the way it wasn't to do with the actual information I set out to find."

Jill spent "hours and hours" looking in libraries to the point of expressing frustration at her inability to find the relevant material. She learnt quite a bit about digestive juice enzymes and plant and animal adaptation, and when she discovered by accident a host of microscopic organisms in the juices:-

> "I went to the library... to the bio medical library and had a look round for books on bacteria, and I found a book on pond creatures. And it turned out that almost all the little things were those found in ponds...daphnia... the most interesting thing I found...was...a couple of little red...they weren't spiders or water mites I couldn't find the name of them anywhere. Then I got a book on water mites and it turns out there are something like two thousand different species ... when I found them I found one book on water mites and from that I found a couple it might look like but not exactly like the little mite".

William used books to find out about the design of hydroponic gardens, as well as about the needs of plants. Following his discovery of creosote: "I've looked through all my books to find something on it but haven't yet gone to the library."

Gavin and Warwick didn't mention hours spent in libraries, but they had read widely on hot air balloon design and

> "Gavin has been doing a lot of research about the solar panels... over the holidays we'll be trying to work out what's the best stuff to make it out of...maybe teflon."

> Do you learn as much doing this sort of thing?
>
> "More. I've learnt a lot...about hot air, aerodynamics .. about the size of balloons ... and I've been doing research about solar power and learning a lot about that too."

Although Phil affected a lack of respect for book learning, he used books to research aspects of his spiders, to aid his drawing and to find out how to sample his lake.

There were many more examples in these case studies of the project leading to both significant learning and significant learning strategies. Students were time and again prompted to go to books by the requirements of the project, and more than one argued that this is not only a more natural way to use books than in the service of a test, but also a better way. This attitude echoes the views of Schwab (1969).

Where do the ideas come from?

The range of project types and styles is quite impressive even in this small collection of case studies. In the main the ideas came either from random events in family life, or from more significant hobbies or interests.

In the former category one could put Brian's metronome design, inspired by his sister having to borrow one, Melissa's "Sitting in a bath at my grandmother's trying to foam soap" or "in the mountains using anti-freeze anti-boil in the car and ... thinking of a substitute", Linda's remembrance of photographs of people floating in the Dead Sea leading to the idea of floating chicken bones, or Valda's noticing differing amounts of corrosion on materials round her pool giving the inspiration for a detailed study.

The inspiration for William's project idea on alternative fuel proceeded thus:

> "We have this wood stove at home... and I saw this white stuff coming out of the wood and I said, what's this? and my Mum said that's creosote. So I collected some in a test tube and a couple of hours later I had it over a burner and I saw this flame coming out of the end of the tube and I thought "this is quite volatile! This stuff is tar... quite incredible!"

In the latter category one could put John's family's long-standing interest in planes as the inspiration for a novel design, Lachlan's experience with construction car kits extended into a scientific study, Melissa's swimming training, Valda's regular watering of her herb collection leading to a study of the effect of additives to the water, and Dale's animals or Sarah's pet rabbit occasioning some animal behaviour studies.

In a few cases the students were specifically helped with the generation of ideas by their family, and that is discussed in the section below.

What is remarkable in this wide range of sources of ideas is just how little school figures in the project choice. While in the schools where the project was done largely during class time the teacher would certainly have had some influence on the direction the project took, in only two of these projects was the idea related to work done in school. In no case did a teacher figure strongly (with one possible exception) in the development of the project.

The Home Environment

All the students had helpful or at least supportive parents. Some mentioned parental help without prompting, for others the help was less significant. Parents of these children were often professionals able to give advice, which is predictable given the types of schools many of the interviewees come from, but it seems this is not at all a necessary condition for commitment to a project. At least half of the students did not receive specific advice from the parents. Stewart's father, for instance, "encourages me but doesn't give much help because he likes me to do it on my own."

Parents tended to help with transport, encouragement with deadlines, supply of simple materials, suggestions for improvement of models, background information, and occasionally partnership in the refinement of ideas. There are a couple of cases of families pitching in with ideas, as with Daniel, whose family seems to be a hive of intellectual activity: "Dad gives my brother and I ideas at times. We all try to think up different ideas to do": and Melissa, whose parents will "sit around and throw around ideas ... mum will say "what about investigating that?"... often you can get ideas that way": and Phil, whose parents "help out a lot...getting ideas straight, setting out, putting it together."

Amost all of the students interviewed have middle class family backgrounds, and that is probably significant for the style of their experience. But coming from a working class background need not be a significant impediment. While it is true that the STS entries tend to come from the middle-class schools, increasingly so of recent years, in the past good entries have come from schools located in working-class suburbs and one of these was "STS school of the year" not so long ago. Selected country schools have a very good record in the competition.

In any case, it would seem that the competition was a very powerful force for some students in putting them in touch with their families in a co-operative and fruitful way.

CONCLUSION

These case studies offer strong support for the notion that learning occurs naturally and inevitably when it flows out of a student's desire to extend her own interests and experiences. This view was expressed strongly by the progressives (Dewey [1963], and Kilpatrick [1928, 1952:315]) and more recently by Wilson (1971). They also represent "instances of autonomy" that challenge our normal assumptions of student behaviour.

There are, of course, matters of the transmission of those "storehouses of knowledge" that represent the disciplines, and matters of practicality in motivating and managing a class of students pursuing their own interests (Tytler 1983), that would make it impractical to centre all teaching around the IRP or its equivalent. The need to include IRP's at a significant place within the curriculum, however, is indicated not only by the student outcomes that have emerged in this study, but from the fact that an increasing number of teachers have found it to be a satisfying method, involving a more powerful and natural view of the student in relation to the educational process (Tytler, ibid).

The case studies have something to say about all such activities (other possibilities are described in Boomer [1983]) that invite students to take responsibility for the serious development of their interests. They stand as examples of the way students work outside the classroom, but also as celebrations of student independence and autonomy. Too often the schooling practices we subscribe to tend to invalidate students' own life experiences. These case studies provide a challenge to us to find educative ways that can match the range of abilities and dispositions that students bring with them to school.

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TWO NON-TRADITIONAL MEASURES OF CHEMISTRY LEARNING: WORD ASSOCIATION AND IDEA ASSOCIATION

Kam-Wah Lee

INTRODUCTION

Three factors have been shown to be important in learning processes in science areas. The first relates to the extent to which the learner's knowledge is effectively integrated or loosely related (Novak, 1977). The second factor is the idea of the activation of a particular part of cognitive structure that is retrieved for learning (Mayer, 1975). The third factor is the subsumption that enables the linking of the existing cognitive structure to new concepts or knowledge to be learned (Novak, 1977). The first factor is concerned with the internal linkages in a cognitive structure (Champagne, Gunstone and Klopfer, 1985) whereas the third factor is concerned with the external linkage between a cognitive structure and new learning content (West, 1975). The second factor relates to the accuracy with which retrieval of a particular part of cognitive structure is achieved for use in learning a particular piece of new knowledge.

The traditional assessing techniques used in science classrooms such as multiple choice, short answer, true/false, fill-in-the-blanks questions are hardly able to assess learning that has occurred in terms of quality dimensions such as the above-mentioned factors, and are more effective at assessing the learner's ability to recall directly bits and pieces of content knowledge, i.e. fragmentary knowledge. Some other traditional assessing techniques such as problem solving questions have been often used to assess the learner's application abilities and skills that are related to the third factor. However, this kind of questions tends to end up getting the "right" or set answers from the students as a result of being constantly drilled in classes.

Various research techniques such as word association, concept mapping, interviewing, etc. have been used in the last decade for probing a learner's prior knowledge or cognitive structure. Some of the techniques used in research in relation to the first factor are application to a group/class or individual situation (Fensham, Garrard and West, 1981).

From an earlier study (Lee, 1986) I was able to show that concept relatedness and idea association which are conceptually related to the above framework are important variables in learning. The technique of word association was employed to measure the relatedness between concepts that are involved in learning. This variable is closely related to the first factor mentioned above.

The cognitive variable, idea association, is conceptually related to the second factor above and the technique used to measure it involved responses to external cues, that are likely to be present in tasks that relate to a given knowledge domain.

A purpose of this paper is to report on the findings about the relationship between these two non-traditional measures and the traditional measures. The investigation involved a quantitative approach. The second purpose of this paper is to discuss about the feasibility of using the two non-traditional measure as alternative forms of assessment in school.

INVESTIGATION PROCEDURE

A replication of data collection was pursued in this study. Two groups of secondary chemistry students were involved. They were Year 11 and Year 12 levels. The subject area for this investigation was electrochemistry. The first group consisted of 214 Year 12 students of 6 schools in Victoria who took 4 tests after they were taught the topic-electrochemistry in Year 12. The four tests were word association test, idea association test, achievement test and problem solving test.

The second group consisted of 60 Year 11 students of 4 schools (four of the above six schools). This group took the same four tests with minor alterations to suit the Year 11 syllabus.

TEST INSTRUMENTS

1. Problem Solving Test

This test consisted of three electrochemistry problems of varying familiarity for the Victorian chemistry course. The Year 11 students were not given Problem 3 since a pilot test showed that it was beyond most of them.

The score for this test was a combination of a measure of success based on some identified ultimate answers, a measure of the problem solvers recalled appropriate knowledge or information in their attempt to solve the problem and a measure of the extent to which the problem solvers have correctly applied the specific knowledge required for problem solving.

2. Achievement Test

This was a test of 17 multiple choice questions on redox reaction and galvanic cell at

Year 12 level. Ten of the questions were used for the Year 11 students.

As traditional, correct and incorrect answers were scored as 1 and 0 for each item respectively. The total scores of 17 items for Year 12 students and 10 items for Year 11 students were used as the scores for the achievement test.

3. Word Association

The test consisted of two tasks: (a) word association and (b) generating propositions. The four concepts: redox reaction, ionic equation, potential difference and E^o value were used as by Gunstone (1980) to provide a score. One minute was given for word associations with each of the four concepts. The students were then asked to generate propositions by writing a sentence or a phrase about the cue word and the associated word in order to validate the responses.

Two measures of the word responses were considered in scoring this test, as follows: (1) Word responses with or without propositions generated and (2) Word responses with propositions generated.

The reason for considering both measures is that some students might have difficulties in putting words together in generating the propositions. "No proposition" did not necessarily indicate inadequate association between the word response and the stimuli.

The Garstkof and Houston relatedness co-efficient (1963) for measuring the relatedness of two words was employed. They defined the relatedness of two words as a function of the degree to which their respective meanings intersected or overlapped. The formula for the relatedness co-efficient is expressed as the ratio of the obtained overlap to the maximum possible overlap.

The relatedness co-efficient for each pair of the four concepts for each measure was computed. The sum of the relatedness co-efficients of measures (1) and (2) was used as the score for the word association test.

4. Idea Association

This test was used to measure the broader associations activated by the cues in the problem statements. The associative responses could be ideas, concepts, words, diagrams or equations. The types of cues that were used in this test were key words, phrases and statements taken from the problems in the problem solving test. Eight key words and three problem stems were used. The time given for each key word was about 1 minute and for each problem stem it was 2-3 minutes.

Three sets of relevant information for the three problems that served as guidelines were used for scoring this test. The responses to the cues (11 items) were identified as relevant and irrelevant by referring to these guidelines. The total number of relevant information in words, diagrams and symbols for the test was used as the score for the idea association test.

RELIABILITIES OF INSTRUMENTS

The Cronbach reliability of the four instruments was measure. The reliability is as follows: Problem Solving Test, 0.87; Achievement Test on Section A and Section B, 0.48 and 0.36 respectively; Word Association Test, 0.75; and Idea Association Test, 0.57.

CORRELATION ANALYSIS

1. Year 12 data:

The Pearson correlation between the four tests was computed and is shown in Table 1. The results which are shown in Table 1 indicate the positive correlation between the problem solving test and each of the two association tests. The achievement test correlates with the idea association test but not with the word association test.

Theoretically, it seemed reasonable to expect that word association or concept relatedness and idea association would be reasonably correlated. In this study the correlation between the word association and idea association is 0.09 which is low. This may be sampling effect.

TABLE 1

	Problem Solving	Achievement	Word Association	Idea Association
Problem Solving	1.0	0.38	0.24	0.48
Achievement		1.0	0.08	0.41
Word Association			1.0	0.09
Idea Association				1.0

2. Year 11 Data

The part-correlation analysis was carried out for the four tests involved. The part-correlation analysis was used to find the correlations between the tests with the consideration of the effect of prior knowledge possessed before the students were taught the topic. In other words, does the problem solving test or achievement test correlate with that part of association test that is not predictable from prior association ability? The results are shown in Table 2.

TABLE 2

		Non-traditional Measure	
		Word Association	Idea Association
Traditional Measure	Problem Solving	0.59	0.42
	Achievement	0.11	0.25

The results shown above indicated that the Year 11 data agree with the Year 12 data in terms of the correlation between the two different types of measures. The problem solving test correlates significantly with both the word association and idea association tests. Again, the correlation between the achievement and word association is low which is 0.11.

DISCUSSION

The results of a previous study (Lee, 1986) provide evidence that concept relatedness and idea association are both actively involved in the process of solving chemistry problems (see Table 3).

TABLE 3

	Strategy process (Teachers or students)	Variables
Stage 1 - Translation of the Problem Statement		
1a	Comprehending the whole problem	PTS*, PPSE, NSRK
1b	Translating the parts of the problem statement so that they have meaning	PTS*, PPSE, NSRK, SK, IA, CR
1c	Setting goal(s) or subgoal(s)	PTS*, PPSE
Stage 2 - Moves towards a Solution		
2a	Selecting information from the translation	PPSE
2b	Retrieving 'rule(s)' or 'fact(s)' from memory	PPSE, NSRK*, SK*, IA, CR
2c	Achieving goal(s) and/or subgoal(s) by explicit or implicit linking of Processing 2a and 2b	PPSE, IA*, CR*
2d	Checking the path(s) of the solution or the answer(s)	PPSE, NSRK, SK, IA, CR

* Most important variable to the corresponding process.

Note: IA - Idea Association.
CR - Concept Relatedness.

NSRK - Non-Specific but relevant knowledge.
SK - Specific Knowledge.
PTS - Problem Translating Skill.
PPSE - Prior Problem Solving Experience.

The results of this study provide the evidence that the measures of concept relatedness and idea association within students' learning experience are correlated to the traditional measures (problem solving questions in this case).

These two results imply that the two non-traditional measures can be used as alternative means to assessing learning as a traditional test. They also can provide insight into the conceptual structure students have and into how students go about linking what they know to the more complex learning tasks that they are intended to learn. Teachers would then be better able to identify the students weaknesses in understanding the concepts and perhaps be able to enhance that understanding.

These non-traditional measures, especially the word association, are not new to many science researchers but they are new to most teachers in the current school assessment systems. In the light of the findings about the importance of these two variables in the learning process, is it possible to use these two non-traditional testing techniques as part of the classroom assessment of students' learning experiences? The feasibility of using the two non-traditional measures in schools is discussed below. In particular, the discussion focuses on the preparation of tests, time required to carry out the tests and the scoring of the tests.

Word Association Test

The preparation of this kind of test is technical but reasonably easy once the important concepts of a topic are identified. One just needs to choose 4 to 6 important concepts within the topic. The time required for the test is flexible and up to the teachers' discretion. In this study the author used 1 minute for word association in column 2 for each concept and an average of about 4 minutes for writing the sentences or phrases for each concept in column 3. Where scoring is concerned, one just needs to count the same associated words between two concepts and then calculate the ratio of the same associated words to the maximum words association. The teachers can use the associated words being validated by sentences/phrases to work out the concept relatedness ratios between each pair of concepts. The total concept relatedness ratios of different pairs of concepts are the score for this test. Calculators would be very useful in doing these computations.

Idea Association Test

The format of the idea association test is different from the word association test. The preparation of the test depends on the use of key words and the problem stem of typical tasks. For each key word or problem stem, enough spaces are given for students to list all the possible associations in words, diagrams, or symbols etc. The key words and the problem stems have to be arranged randomly so that one can tap on a wider range of associations instead of only one sort of association for one problem. Again, the time required for the test is flexible. The author used 1 minute for each key word and about 3 minutes for each problem stem. In this study about 15 minutes were used for the test consisting of 11 items. The teacher controls the progress of the whole test. She or he announced the words for each item and times the students in making their written responses. To score the test the teacher has to count the numbers of information relevant to the solution of the task including words, diagrams, symbols, etc. This would be easier if the teacher had a list of relevant information as guidelines for scoring.

CONCLUSION

The word association test and idea association test are open-ended tests which assess students' linking ability and also their accuracy in retrieving the relevant knowledge. These tests break through the "spoon-fed" and "drilled" types of assessment. The earlier study has shown that linkage of knowledge is one of the influential factors in determining problem solving performance (Lee, 1986). A replication study has confirmed the earlier findings that these two non-traditional measures assess learning performance as do the traditional methods. Apart from providing the numerical scores for the learning performance, the two non-traditional tests also provide teachers with useful qualitative evidence of how students proceed with their learning and with their understanding of concepts. The technical procedures of setting, carrying out and scoring the tests are reasonably easy to handle. On the basis of the evidence shown, it is suggested that the word association and idea association tests should become part of the regular testing of chemistry learning in schools.

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TEACHER CLASSROOM MANAGEMENT STYLES WITH BEGINNING HIGH SCHOOL STUDENTS

Jim Butler and Warren Beasley

> Initial encounters are uncertain, problematic and exploratory in character compared to routine encounters when the rules have been stabilised. More needs to be known about the strategic resources brought into play by teachers and pupils as they mould the social and academic topography of different kinds of classrooms (Beynon, 1985, p. 4).

INTRODUCTION

This paper reports on some of the more personal resources that the teacher brings to initial encounters. It focuses on the teaching styles of four science teachers beginning the school year with entering Year 8 students in science at three metropolitan state high schools.

THE THEORETICAL BACKGROUND TO THE STUDY

The impetus for the investigation was Doyle's (1979) hypothesised functional relationship between the potency of student misbehaviour and time. The relationship is shown in Figure 1, where t' is time zero when the teacher initially meets the class; t" is the time when a state of equilibrium is reached; and t is the occasion when the class disbands for vacation. The potency of student misbehaviour (Y axis) is a composite measure reflecting both the frequency and seriousness of the events.

The actual magnitudes of t' and t" were not hinted at by Doyle (1979) so to design this study we questioned a sample of science teachers. They suggested that it took about six weeks for them to feel that the students knew and followed their classroom and laboratory rules. We then collected data on a schedule that sampled a two month period in an attempt to detect the hypothesised "hump" in the intensity and frequency of student misbehaviour.

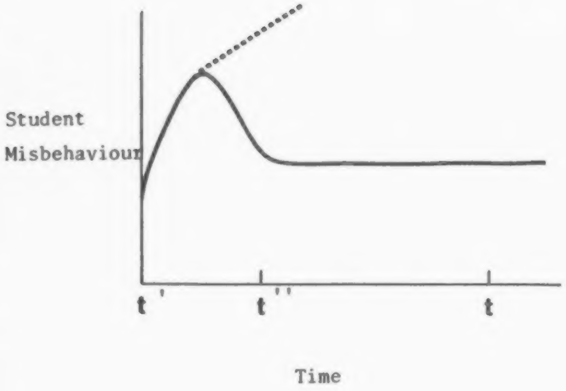

Figure 1. Student misbehaviour over time (After Doyle, 1979)

At the time when this study was designed most research on classroom management emphasised the "centrality to management of rule-setting, teacher sanctioning of behaviour, and the socialisation of the children to the teacher's rules and procedures." (Evertson & Emmer, 1982; p. 486). But almost certainly these results are only a part of the skills and resources that the teacher brings to the initial encounter. The construct of "teacher as manager" coerces these results, useful as they are; but they must be taken in their context. On the other hand, this research constructed case studies of four teachers and expanded beyond the concept of "teacher as manager" to include many other more personal factors. The management skills identified by the previous research would be expected to be present but we were looking beyond those.

The expectation of finding something different was based on the work of the English ethnographers (Beynon, 1985). After an exhaustive review of the literature on initial encounters Beynon states: "To date it is still the case that relatively little is known about just what features are considered most important by groups of teachers and pupils in their classroom relationships..." (p. 38).

To introduce a perspective broader than management a wider set of categories were needed. The category system that was found most useful in the present study lists four purposes that teachers much accommodate in the classroom (Westbury, 1980). They are: coverage, mastery, affect and attention. The first two have a curriculum context and point up the classic dilemma that faces all teachers, particularly in mixed ability classes, concerning the pace with which the curriculum can be covered. The latter two categories have more of a management focus but they introduce the oft forgotten notion of affect in the classroom, and introduce the trade-offs that the teachers must make between interpersonal relationships and role and status relationships, "It was almost as if what they (teachers) had said about establishing dominance was in conflict with their subsequent aspirations (concerning personal relationships with their class)" (Wragg & Wood, 1984; p. 62). On the other hand Edelsky et. al. (1983) found that the teachers they studied had three goals in establishing and maintaining attention: to get pupils to enjoy their intellects; to get along together; and to see opportunities to learn everywhere. These latter teachers appear to solve the dilemma in a vastly different way to the teachers that Wragg and Wood (1984) observed.

The impression one gets from the published literature is that initial encounters between teachers and students show little variation and share many essentially generic characteristics. However, there are reasons to question this position. The four Westbury categories could be given different emphases by different teachers; and different emphases may be appropriate for different contexts, be they the beginning, the middle or the end of the school year. The classroom situation is always a blend or mixture of curriculum, affect and control; the teacher, the students and the context determine the mix together; and it must be negotiated almost daily. Some mixes lead to chaos (Doyle, 1979; p. 51), others lead to a rigid, repressive discipline (Beynon, 1985; p. 49) while others lead to enjoyment and self-disciplined learning (Edelsky et. al., 1983).

THE FOUR TEACHERS AND THEIR MANAGEMENT STYLES

The four science teachers in this study are drawn from the group of teachers described in the previous report (Butler et. al., 1980). In terms of the measures reported in the previous study these four are "average" teachers. The extensive case records assembled on the four teachers will be abbreviated and several of the significant segments reported.

The data for the cases was collected in the following forms:

1. Four complete Year 8 science lessons, one in each of the first four weeks of the school year, were videotaped. The levels of student attention and misbehaviour were coded as described in Butler et. al. (1980).

2. The teachers' behaviours in each of these lessons were analysed from the videotapes by a trained observer.
3. The activity segments in the lessons were coded as described in Butler et. al. (1980).
4. The four teachers were interviewed and the data collected in the previous three steps discussed with them. They were also asked to talk about their understanding of the early part of the year when they meet a Year 8 science class.

A profile of each teacher will now be synthesized from the case studies.

1. ELEANOR. She is an experienced teacher in her thirties enrolled in a research masters degree in microbiology. From the videotapes the students were coded as inattentive at the following rates for the four lessons: 5%, 7%, 6% and 4% of the total lesson time, respectively. The four lessons focused on teaching the students the scientific method, and the predominant setting was small group activity (SGA) supported by whole class (WCA) teacher demonstrations and expository teaching. The rules of appropriate behaviour in the science laboratory were established initially via a list of rules given to each student. These rules were constantly enforced. A questioning format rather than direct commands, and a personal approach were directed at students who did not keep the rules.

In the interview data Eleanor revealed that her intention was to establish appropriate student behaviours in the science laboratory including the safe handling of equipment and materials; and to have the students being considerate so that no damage or inconvenience was caused to others. But the central focus was that they learn the rigorous scientific technique from the very beginning. Her intention was that the students learn the correct method, and then to build them up to an independent functioning mode in the laboratory.

Summing up her intentions at the start of the year Eleanor stated that she built up student expectations about the high level of thinking and heightened sense of responsibility in science lessons; about the demands of science as a discipline; and about the demands of "this teacher".

2. GEOFF. Geoff is tall and in his early twenties, and has taught for more than five years. The coded videotapes showed the following levels of student inattention in the four lessons: 4%, 13%, 17% and 9% of the total lesson time respectively. The lessons were teacher centred with WCA expository teaching dominant, but with one SGA setting using scientific apparatus and some use of brief individual activity (IA) settings.

The expository teaching featured prolonged, rapid-questioning sequences on science familiar to students, with the emphasis on coverage rather than mastery and on facts rather than explanations. The establishment of the rules of behaviour occurred as the students failed to meet Geoff's expectations which were then conveyed in a direct command.

In the interview Geoff stated that the main purposes of his management techniques were for the teacher and the students to get to know each other, to settle the rules so that the classes would run efficiently, and to get the students interested in science.

The extensive questioning of the students was employed as a deliberate management device by Geoff. He attempted to cover the whole class with questions to get ideas, understanding and attention. This technique also allowed student names to be learnt and for the establishment of the important rule that one person may only speak at a time. Most other rules were established when required and some laboratory rules were similarly promulgated.

3. JOYCE. Joyce is an experienced teacher in her thirties. The coded videotapes showed the following levels of student inattention in the four lessons: 4%, 6%, 2% and 6% of the total lesson time respectively. The lessons were predominantely WCA settings with teacher-centred exposition associated with periods of IA for students to "write up" notes. The teacher exposition focused on teaching science concepts, developing scientific skills, learning to handle scientific equipment and the declaration of safety rules and safe practices. The major skill training was on the correct "writing up" of experimental data and large periods of time were devoted to helping the students to reach this requirement. The teacher spoke in a strong firm voice with a serious but pleasant facial expression.

Rules of behaviour which related specifically to the laboratory situation were issued on paper to each student in the first lesson, and they were expounded and demonstrated by the teacher. The more general classroom rules were established as situations presented themselves except for those relating to the writing up of scientific experiments. These latter rules were elaborated repeatedly and in a very direct communication style.

In the interview Joyce said that her aims were: to develop a comfortable relationship with the students; to get to know them as soon as possible; to develop in them the correct basic laboratory skills through modelling and imitation; to teach them to write up experiments properly by keeping good records and drawing carefully. She placed equal importance on getting to know the students and teaching science.

Joyce expected that the students would be following the correct "writing up" procedure within a few weeks. It was so important because it was an essential part of scientific reporting and because it developed organisational skills and provided the students with a record of their own work. Students did not learn this skill in primary school and so it needed to be demonstrated and instilled in Year 8. Student work-books were also a requirement for teacher inspection. Joyce also noted that very explicit instructions had to be provided in relation to laboratory safety.

4. **STAN.** Stan is an experienced teacher in his late twenties. The coded videotapes showed the following levels of student inattention in the four lessons: 10%, 4%, 13% and 6% of the total lesson time respectively. The lessons were each highly interactive: the WCA expository parts had high levels of teacher-student interactions, and the SGA segments had high levels of teacher-student and student-student interaction. The lessons were about equally divided between these two settings with brief IA segments used for mini-revision tests. Both the WCA and SGA segments were characterised by prolonged and intense questioning sessions, eliciting and probing student explanations; Stan never foreclosed the discussions by "telling students", but rather provided regular syntheses of the students responses. The expository segments focused on using everyday examples to teach science concepts and the examples used had a "person" orientation. The experimental sessions involved students examining and discussing rock samples rather than formal experimental procedures and scientific equipment.

Stan's communication style was personal, democratic and co-operative; acknowledging student effort, their thinking and their feelings, and actively trying to genuinely involve them. The co-operative personal approach was maintained in communications that related to the establishment of rules of behaviour.

In his interview Stan advocated developing a set of general rules gradually, providing comments quietly to the whole class on the appropriateness or otherwise of things that occur in the classroom. It was important that the students find their own feet, and then to establish rules which were negotiable. The rules regarding behaviour in the laboratory were not negotiable and were given to the student on a piece of paper. Stan preferred private rather than whole class disciplining. This means going up beside the student in the room or taking the student outside the room.

Stan's central message was the importance of the teacher and class getting on together. He enjoyed being close to the class. The learning of science per se was not as important as the establishment of a co-operative classroom environment. Practical classes were not important early in the year.

DISCUSSION

Starting with the off-task behaviour data it is clear that the Doyle "hump" was not detected. The other sixteen teachers that were in the study were as variable as these and no pattern emerged. For the pattern that Doyle (1979) hypothesised to have been apparent in our design, several assumptions would have had to hold. The teachers and students would have had to uniformly contest the rules that were to apply in their classrooms. The initial lessons would have to reveal high status teachers imposing order on challenging groups of students. The teachers lose ground for a while as the students escalate their challenge, but finally triumph as the students are out-manoeuvred by superior knowledge and management skills. The prize at stake in the contest is the character of the order in the classroom, the territory is staked out in terms of opposing classroom rules. The management research tradition in which this project started assumed that image of initial encounters between teachers and students. The videotaped lessons that we collected were initially analysed within the categories of the management tradition: student time on task, the number of rules, responses to disruption, clarity of instructions and directions, settings chosen, ... But the pattern we were looking for would not emerge and so we went on to collect the further data.

The picture that was then revealed, the diverse purposes, resources and expectations that the teachers had, made our initial research goal and design seem very inappropriate. The inner workings of these four classrooms, at least as far as the teachers are concerned, are dissimilar but the levels of student attention are not. The new categories revealed that the initial encounters between teachers and students are richly contextualised by the teachers who are free to select purposes and resources that take similar groups of students into divergent paths. It seems that to imagine a student's science education as a progression through the syllabuses from Year 8 to Year 10 is far too simple. What a student achieves in each of the three years is not the goals of the three syllabuses but that which resides in the teacher purposes. In this study, these purposes are revealed as early as the first week of school. It leads to the image of each science class as being taken on a guided tour of the palace called science each year. Each Year 8 teacher starts in a different room in the palace and goes in a different direction; the same is probably true for Year 9 teachers and Year 10 teachers.

It is apparent that the data that can be gleaned from a series of videotaped lessons can reveal much about the teachers' purposes. The interviews confirmed the observational data. The teachers knew they were behaving the way they were described and had the reasons ready to hand.

Moving now to the specific differences in teaching style. Starting with the coverage/mastery categories it is clear that these four teachers take very different views of their meaning. This is particularly true of the affect/attention categories. Geoff puts most emphasis on student attention and uses factual coverage to assist in that goal. Stan emphasises the affect of the class members for each other and takes coverage/mastery to mean the acquisition by the students of the enquiry process and observational skills abstracted from the geological content. Eleanor takes the same view as Stan about coverage/mastery but does so in a definite experimental fashion with plenty of scientific apparatus. The goal is the developing scientist and it is affect for the subject that predominates and student attention is presumed to follow from the richness of the classroom resources. Joyce on the other hand emphasises affect to mean a very formal courteous treatment of each person and insists on student attention. In contrast to the others she takes the coverage/mastery goals with extra seriousness and takes them to involve students in being able to write very orderly, precise and accurate notes. Geoff seems to focus on an external, verbal, science content oriented product to gain classroom order; Joyce, on an external, written product to prepare orderly scientific minds; Stan, on an internal affect for people and general thought processes; and finally Eleanor, on the development of enquiry oriented experimental scientists. The students of these teachers are receiving very different science educations.

The teachers each have a distinct style which takes students into diverse rooms of the science palace which complicates the concept of achievement and curriculum and science education.

The present study shows that teachers have very definite ideas about their performance capabilities and goals in settings. It is almost as if teachers don't even share an understanding of what can be achieved by questioning settings or small group settings. So there is no way that they can see how to exploit the resources other teachers bring to their meetings with students.

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STUDENTS' UNDERSTANDING OF BASIC IDEAS OF THE SECOND LAW OF THERMODYNAMICS

Reinders Duit and Sofia Kesidou

ON THE ROLE OF THE SECOND LAW OF THERMODYNAMICS IN SCIENCE INSTRUCTION AT LOWER GRADES

This research is aimed at students in lower grades, i.e. students of about 13 to 16 years old. The intention was not to teach quantitative versions of the second law (e.g. employing the entropy concept) to these students, but rather make them familiar with basic qualitative ideas of this law (see Fig. 1). The main aims of teaching these basic ideas are presented in Fig. 2.

Irreversibility and asymmetry in nature
All "real" processes run by themselves in only one direction. Heat never travels on its own from a cold body to a hot one. There is no cyclic heat engine which does work only at the cost of cooling down a heat reservoir.

Energy degradation
In every process running in the real world energy loses value, i.e. is degraded.

Tendency toward...
...even distribution of matter and energy,
...disorder,
...ignorance (i.e. loss of information).

The destructive and the constructive aspect of the second Law
Usually only (or mainly) the "destructive" aspect of the second law is emphasized. But there is also a "constructive" aspect. The creation of new structures does not occur "in opposition to" the second law but because of it. Atkins (1983) stated this idea very clearly: "The very nature of nature is decay but decay drives creation".

Fig. 1: Qualitative ideas of the second law.

(1) Insight into the "nature of nature"
The ideas provide a rather deep insight into the "way nature works". Students acquire access to fundamental principles of science.

(2) Understanding of energy supply issues
Undoubtedly understanding of problems of energy supply in society needs a sound insight into the mentioned basic ideas of the second law, especially into the aspect of energy degradation.

(3) Understanding of the energy concept
Not even the science concept of energy appears to be understandable without the aspect of energy degradation. The aspect of energy conservation seems to contradict experiences in the real world where degradation is the dominating impression.
Therefore, energy conservation and energy degradation both have to be regarded from the very start of teaching energy (see Duit, 1986).

Fig. 2: Aims of teaching basic ideas of the second law.

Research on teaching and learning the second law

Quite a number of papers on the second law is available in the area of science instruction but there are also neglected fields.

Firstly, studies on students' conceptions and students' conseptual change in this area are lacking. There are some studies on students' conceptions of energy degradation (see e.g. Solomon & Black, 1983; Brook & Driver, 1986). There are further studies on students' ideas of "order-disorder-information" (see Schaefer, 1983) and Piagetian studies on the idea of chance (see the summary of Bliss, 1978). But we know almost nothing about the other basic ideas of the second law mentioned in Fig. 1.

Secondly, we do not know whether it is possible to introduce the newly developed teaching materials into science classes on a broader scale. We do not have, for instance, studies on teachers' "attitudes" towards teaching the second law in lower grades.

Our research in the field of the second law starts from the mentioned deficient fields. In the following, studies on teachers' "attitudes" toward teaching basic ideas of the second law and curriculum development activities will be outlined only briefly. More space will be given to studies on students' conceptions of irreversibility.

Developing teaching modules; studies on teachers' attitudes towards teaching the second law

Initially we analysed and developed teaching modules and our first results were published in an issue of a German physics and chemistry teachers' journal on "energy degradation and disorder" (Duit, 1987).

In the matter of teachers' attitudes we started with a questionnaire (Fig. 3).

- Which aspects of the second law may be taught already in grades 5 to 10 (i.e. to 10 to 16 year olds).
- What are the reasons to start teaching aspects of the second law at this school level?
- Does the second law play any role in your science teaching?
- Please give the verbalization of the second law you think is best suited for students in grades 5 to 10!

Fig. 3: Questions for teachers' questionnaire on the role of the second law in lower grades.

The questionnaire was only the first step in the communication process between the teachers and us. We plan to send the above mentioned issue of a journal to the teachers. Teachers will be asked to comment on the proposed teaching modules and to try one or the other proposal in their own classes.

STUDIES ON STUDENTS' CONCEPTIONS OR IRREVERSIBILITY

The second branch of our research is devoted to studies on students' conceptions. These studies have been carried out in the "spirit" of the "student' conceptions movement". In a first series of interviews we wanted to find out whether several years of physics instructions had provided students with conceptions necessary to understand irreversibility and whether ideas of irreversibility had formed through "traditional" physics instruction (i.e. physics instruction in which aspects of the second law had not been given much attention).

Our research is a start into a new area. So far, we have concentrated on "detecting" conceptions. Studies on conceptual change may follow. But they can only be planned if we know much more about students' conceptions of irreversibility. The studies are considerably influenced by physics tradition. The phenomena we present to students are, for instance, good old friends from physics textbooks. They deal with processes of heat exchange (temperature equalization) and with the irreversibility of the movement of a falling stone as well as of an oscillating pendulum:

> Temperature differences always equalize, they never increase without other driving processes; a stone lying on the ground never rises and a pendulum never starts moving at the cost of cooling the environment.

Of course, other accesses to students' conceptions of irreversibility are possible and interesting. It would be very valuable, for instance, to discuss a number of irreversible processes in the natural and technical environment in order to investigate whether students are aware that irreversibility is an important trait of processes around them. We are only at the beginning of the exploration into students' conceptions of irreversibility. As yet, we have investigated only a rather limited section of this field. In the following some preliminary findings are discussed. They deal with processes of heat exchange.

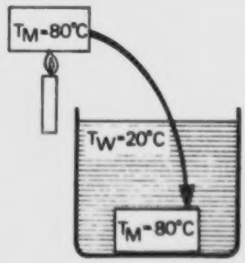
On Methods of the Studies

As mentioned already the studies are carried out in the spirit of the "alternative framework movement" (as described by Driver & Erickson, 1983; Gilbert & Watts, 1983). It is our aim to map (so to speak) students' conceptions in a certain area of phenomena. Our approach, therefore, has much in common with what Marton (1981) has called phenomenography.

So far, we have carried out 14 clinical interviews with German 10th Grade Gymnasium (high school) students. These students (about 16 years old) had had four years of physics instruction (two lessons a week very year) in which heat, temperature and energy had been taught in a somewhat traditional way.

Students were confronted with situations sketched on cards. The tools sketched on them were also presented but experiments were not carried out. As is usually the case in clinical interviews we started with rather open questions. The main intention of the interviewer was to help students to develop their own ideas. But two types of interventions were used. At specific places of the interview we reminded students of models and concepts taught in physics instruction (e.g. the particle model and the energy concept) if they had not mentioned them so far. We asked for explanations employing these models and concepts. We further tried to investigate the consistency of students' explanations in different parts of the interview. Therefore, several times we confronted students with answers they had given before.

The tasks of the study on heat exchange processes



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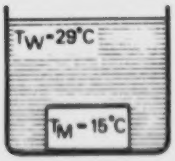

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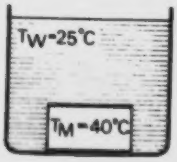

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Fig. 4: A hot piece of metal is put into cold water

Fig. 5: It is possible that this state occurs after some time?

Fig. 6: Is it possible that this state occurs after temperatures had equalized?

The first process (Fig. 4) we discussed was heat exchange between a hot piece of metal (80°C) and cold water 20°C). Students were asked to predict what would happen and to explain their predictions. After that they were confronted with the situations sketched in Fig. 5 and Fig. 6. We wanted to know whether these states can occur or not. In both of them temperature differences arise after temperature equalization. In Fig. 5 the direction of temperature change is not altered (i.e. metal becomes colder, water warmer during the whole process) whereas in Fig. 6 there is a change in the direction of temperature change (so to speak a running back to the initial state). It is this confrontation we expected to provide some insight into students' ideas of irreversibility.

In principal the same questions were asked in another task on heat exchange between two bodies of the same material, namely metal plates. The last task on heat exchange confronted students' with a classical verbalization of the second law, namely: "Heat never travels on its own from a cold body to a hot one".

Students were asked to explain this statement and to discuss whether it fits their experiences and the situations presented in the interview previously.

Some general findings concerning "heat - temperature - temperature equalization"

There are many studies available on students' conceptions of heat and temperature (see e.g. Tiberghien & Erickson, 1985). Our interviews have reconfirmed many findings of these studies. Also our students, for instance, had severe difficulties to differentiate adequately between heat and temperature.

When students' conceptions of temperatue equalization are concerned a majority of around 80% were of the opinion that the temperatures of the hot metal and the cold water in Fig. 4 tend to equalize. But they did not necessarily think that at the end of the exchange process both bodies would have the same temperatures. Namely 8 out of 14 students were of the opinion that the situation of Fig. 5 may occur and 3 out of 14 thought the situation of Fig. 6 may be possible. Even the students who thought that neither situation (or Fig. 5 or Fig. 6) is possible did not necessarily appear to be of the opinion that the temperatures of metal and water tend to the same figure. Only two of them mentioned this fact explicitly. Two others explained that the same figure is achieved only after some oscillations.

Students' ideas of heat exchange processes

Physics views heat exchange as a process of thermal interaction between the bodies involved. The process of Fig. 4, for instance, is viewed as thermal interaction between the hot piece of metal and the cold water. Of course, there are also interactions with the surroundings. But they are of subordinate importance (at least in the beginning). It is interesting that a remarkable number of students hold a somewhat different view. For them the interaction between metal and water appeared to be of subordinate importance. They viewed the processes as caused by some external factors such as "something in the surroundings" or "energy input".

There were some other "alternative views" of the heat exchange process worth mentioning:

-Temperature equalization was explained by properties of the bodies involved (e.g. the property to "be hot" or to "be cold" or the ability to "give heat" (or cold respectively to other bodies). Usually only the properties of one of the bodies involved were considered.

- Two students accepted that a body cools when surrounded by air but they had some difficulties that bodies can also be heated by the surrounding air (if air has a higher temperature than these bodies). The students' opinion that air has only the quality to cool other bodies could not be shaken in the interview.

- As is known from other studies that heat and cold are often viewed as entities of their own. Many of our students also used these two entities to explain heat exchange. Some of them explained, for instance, that heat is attracted by the cold body until heat and cold have neutralized.

Students' ideas of the rise of temperature differences

Our studies aim at investigating students' conceptions of irreversibility. It is, therefore, of specific interest how students explain the rise of temperature differences after temperature equalization (see the above mentioned situations of Fig. 5 and Fig. 6). We found the following ideas:

- Inertness of heat

As already mentioned many (8 out of 14) students thought that a temperature difference may arise out of equalization when the direction of temperature changes does not alter (situation of Fig. 5). Only a small number (3 out of 14) thought that this is possible when the direction of temperature change is reversed (situation of

Fig. 6). It may be that the idea of "inertness of heat" lies behind this finding. A student, for instance, used this explanation:

"Heat transfer started and does not stop at once when temperatures have equalized".

Another student used the analogy with the oscillation of a liquid in an u-tube.

- Different properties of substances

Most students who thought that the rise of a temperature difference after equalization is possible explained that different properties of the bodies involved are responsible for this. Properties mentioned were: density of substances, "nature" of substances, ability to store or conduct heat, different heating or cooling times.

- Different properties of atoms or molecules

Some students tried to explain different properties of the bodies involved by different properties of their atoms or molecules. This, for instance, is the explanation of a student who accepted that the situation of Fig. 5 is possible:
"I think wateratoms have a smaller mass, are more movable than the atoms of the metal, therefore, the metal's atoms cannot stay so much in movement, i.e. oscillate, which is equivalent to heating, temperature, therefore, I guess, that water molecules are more movable and therefore, water stays warmer".

Students' comments on "heat never travels on its own from a cold body to a hot one".

There are two groups of reactions to this classical verbalization of the second law which appear to be of general interest:

(a) The sentence is accepted as plausible but interpreted in an everyday and not in the physics framework

Two students, for instance, said that the sentence is right because cold bodies contain cold (or give cold respectively) and not heat.

(b) The sentence is interpreted in acceptable manner but answers previously given in the interview are in contradiction to it

As has been mentioned we reminded students of answers they had given previously if there appeared to be contradictions. Two main reactions of students occurred. Some were not able to see any contradictions and did not change the idea presented previously (see the first of the following examples). Others changed their view (see the second one).

I: "And what about this example? You said here (situation of Fig. 5) that it is possible that the piece of metal has the temperature of 15°C and the water of 29°C. Do you see any contradiction?"

S: "No, the metal had been 80°C, it goes from warm to cold".

I: "But we said that there was a moment where temperatures were the same. What about the process after that moment. Doesn't heat then travel from the cold to the warm body?"

S: "Yes, for a moment elementary particles cannot oscillate as well as those of water. It is here a question of the substances. There is no other reason that water is heated, simply caused by the substances.

The student of the second example in the interview so far had expressed the idea that a body's ability to receive heat or to give out heat is a property independent of the temperatures of the bodies in the surroundings. Such idea was mentioned already (see the students who thought that air always cools and never heats).

S: "The way I understand the sentence it means that I was not right before".

I: "Why?" "What do you mean?"

S: "O.K., that means that a body cannot give out heat actively; hence a body does not give out heat voluntarily, on its own; but because the other body, the colder one, tends to take in this energy; if the body gives out heat, it doesn't do it voluntarily but it is so to speak forced to do it".

Although it is not totally clear from this passage of the interview that the student "really" means (which is a well known problem of interview interpretation in general) we think that it indicates a remarkable conceptual change. The student moved from viewing the ability to receive or give out heat as properties of the body alone to properties of the bodies involved as well as properties of their interactions.

CONCLUDING REMARKS

The findings presented above stem from a first series of 14 interviews. Further interviews will enlarge the preliminary results and insights available so far. What can be said about students' conceptions of irreversibility already now appears to be this. Most students have intuitively the correct idea that temperature differences tend to equalize and that the processes will not totally run back after equalization (i.e. the original temperature difference will not occur again without other processes involved). But there is a remarkable number of students who think that a certain temperature difference may arise after temperature equalization. So far, we do not know well enough whether students are aware that temperature equalization processes in principle are always running only in one direction. The further interviews planned will try to investigate this in a little more detail.

It is remarkable that students' ideas of the processes running in natural direction are mainly based on everyday conceptions and not on the physics ones taught in school. A remark aside on findings of the other irreversible processes in our interviews (namely a stone falling down or an oscillating pendulum coming to rest) may be interesting. There too, the processes running in natural direction very often were not conceptualized within the physics framework taught in school but within an everyday frame. If our preliminary findings are reconfirmed we have to conclude that students very often do not achieve a sound physics framework to understand irreversibility during several years of physics instruction. Of course, this conclusion is by no means surprising when taking the many studies on students' conceptions in other areas into consideration.

Is it possible to explain the idea of irreversibility within students' everyday ("alternative") frameworks? No short answer can be given. On the one hand the idea of irreversibility appears to be in accordance with many traits of everyday conceptions. In this respect it is true that the idea is quite near to everyday experiences (see e.g. Haber-Schaim, 1985; Duit, 1983). But on the other hand there are ideas within everyday conceptions which contradict irreversibility (e.g. the idea of many students that temperature differences may arise after temperature equalization).

Therefore, there appear to be good reasons (and excuses) for further research to be carried out in this area.

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INSTANT USE OF EVIDENCE FROM COLLABORATIVE RESEARCH ABOUT PHYSICS TEACHING

David Treagust, Monica Leggett, Peter Glasson & Bill Wilkinson

INTRODUCTION

During first semester, 1987, a team of four researchers was engaged in a classroom study designed to identify and document the manner in which content knowledge was transmitted in the classroom by the teacher and how this knowledge was acquired by students. The four researchers were one physics teacher in whose classroom the study was conducted and three university personnel who had specific interests and competencies in science education, teaching physics and classroom research. The study involved a collaborative research design as described by Watt & Watt (1982) and Kyle & McCutcheon (1984) and was not unlike Baird, Mitchell & Northfield's (1987) collaborative action research. Such a research design was used since it was considered to be the optimum means to achieve a successful outcome for our goals. As the study progressed and data were collected, the subsequent interactions concerning the interpretation and implications of our observations lead the teacher-researcher, Peter Glasson, to alter his teaching for subsequent lessons in the light of the findings from the research. This paper reports on how the study enabled the teacher to reflect on his practice and use research evidence from our collaborations to improve his physics teaching.

METHODOLOGY USED IN THE STUDY

The researchers made observations and collected data during two 6-week periods which were each followed by two 3-week periods where no classroom observations took place. Findings were discussed on a daily and weekly basis. At all times there were at least two researchers in the classroom - the teacher and one or two "observers". An interpretive research methodology (Erickson 1986) was used which incorporated data collection, data analysis and data interpretation procedures. During each week the class met for four, 50-minute lessons. Sources of data included field notes from classroom observers, student working files and tests, teacher notes on lesson planning and distributed class notes, information from student questionnaires and interviews with the students and with the teacher. In addition several lessons were tape-recorded for more detailed analysis. All four researchers interacted as soon as possible after the observations were made to interpret data from the field notes, lesson transcripts and interviews. These interactions provided a focus for subsequent observations and construction of assertions, the validity and reliability of which were carefully considered by triangulation using supportive data from as many sources as possible and by congruence among as many researchers as possible.

During the course of the study, three interrelated factors contributed to the changes that occurred in Peter's classroom, namely: the nature of the study, continuous feedback, and reflection by the teacher.

Nature of the study. The aspects of the study that made it different from our previous research, where examplary teachers were observed (Tobin and Fraser 1987), were the holistic approach to observing the classroom, the involvement of the teacher as an integral member of the research team, and the extended length of time in one classroom. The research team observed the entire classroom environment and allowed their observations to drive the study. Since the teacher was a member of the research team he was involved in the study as it progressed. Information was shared equally among the group at all times so the teacher heard what the other members of the team said about their observations and they listened to the teacher's thoughts and ideas about each teaching activity. The involvement of the teacher with other science educators in an holistic study of his classroom appears more likely to bring about a fundamental change to the teacher's philosophical basis of teaching. The teacher's classroom became the centre-stage of the study and key questions were highlighted and analysed in depth by the research team on a weekly basis.

In conducting this study we were cognisant of the design criteria for collaborative research described by Watt & Watt (1982). Broadly speaking they believe that collaborative research should benefit the teacher and the students as well as influencing the development of improved classroom practice. Watt & Watt (1982, p.135) believe these two goals are best served by: (a) classroom research which offers benefits to all participants, (b) the teacher, students and school administration being involved in planning and implementing the project, (c) the research being conducted with honesty, openness and mutual respect and (d) observations and data collection being as unobstrusive and natural as possible. This study attempted to achieve these goals.

Continuous feedback. The second major factor in facilitating change was the continuous feedback given to the teacher through written reports and discussions with other members of the research team. The students also provided their own feedback informally in the way they responded to various activities and formally through questionnaires and interviews. The feedback provided the teacher with a mirror to see clearly what was happening in his classroom and enabled him to initiate changes in his approach and observe very quickly how these activities were implemented. Whenever possible, the feedback was neutral and, although at times certain activities were either supported or not supported by the other members of the research team, few suggestions were made about changing teaching practice. Without such continuous feedback it would have been difficult for the teacher to easily identify weaknesses and evaluate changes.

Reflection by the teacher. The third factor which encouraged change was the act of reflection by the teacher. All able teachers consider the success or otherwise of lessons and make some conscious effort to change activities where necessary. However, if need for change and mechanisms for acceptable change are not eaisly identified, they are often not acted upon. In a situation where there is continual feedback through collaborative teacher-researcher interactions, such reflective thoughts can be carefully analysed until alternatives are tried, and the results, feedback and further reflection are made on this information. In brief, the feedback-reflection-change-feedback cycle kept up the momentum for change and the energy, interest and expertise of the research team provided a fertile environment for the generation of new ideas.

BACKGROUND INFORMATION

The students involved in this study were one class of Year 11 (aged 15-16 years) who were studying the first year of a two year physics course which leads to the Tertiary Entrance Examination in Western Australia. Students in Year 11 and 12 are usually among the top 50% of academically able students of the Year 8 (first year of secondary school) cohort. The 24 students were informed at the outset of the study that one or two of the three observers would be in the classroom with their teacher throughout the first semester. Initially letters were sent home to parents to ensure that such an arrangement was acceptable. The students attended a private Catholic co-educational school in a working and middle class area of metropolitan Perth.

Peter had been teaching the Year 11 physics course for four years previous to the study and had developed and modified an approach to teaching physics with which he was pleased and confident. Informal feedback from the students over the four years was positive and enrolments in physics were high and compared very favourably with those in chemistry. The teacher was aware of some aspects of his approach which could be improved but no substantial change had occurred over the last two years.

At the commencement of the semester students were provided with a study guide which, for each section to be studied, listed references in two textbooks, questions and/or problems from up to five sources, and practical exercises to be completed. For the non-practical part of the physics lessons, students were expected to read relevant references, make up a set of summary notes and answer a selection of the questions and problems. Whenever difficulties were encountered students were requested to seek assistance from the teacher. Occasionally Peter would stop the class if he became aware of a large number of students with the same problem. In this situation he would direct those students with difficulties to go to the front of the class and he would work through a problem on the whiteboard.

FINDINGS

The findings from this part of the study are presented in terms of two assertions which emerged during the course of the semester.

Assertion 1:

The collaborative research provided the teacher with an enhanced philosophical basis for his physics teaching.

At the commencement of the study, Peter held a number of beliefs about physics teaching which collectively formed the philosophical basis for his classroom practice. These beliefs were verbalised to students in the introductory lesson and stated in the initial handout. In addition, Peter's beliefs about his teaching were either stated in after-class discussions with members of the research team or were identified by the other researchers as being reflected in his classroom practice. Initially, Peter's philosophy was centred on creating an appropriate learning environment where students could construct their own knowledge. In this environment, students were expected to take responsibility for their own learning while a consious effort was made to maintain a classroom environment which would improve each student's self-esteem. The role of the teacher was to create this learning environment and provide assistance to students as they needed it. The findings of the research served to strengthen this aspect of Peter's philosophical basis of teaching. Details of this learning environment and the way Peter managed his Year 11 physics class as they progressed through the semester are described in Wilkinson, Treagust, Leggett and Glasson (1988).

At the same time, Peter became aware of certain deficiencies of his own teaching philosophy. Based on the feedback from the collaborative research and his own reflection processes, Peter realised that many of his beliefs and consequent actions were focussed primarily on the learning environment of the classroom; the ways in which the students learned the physics content had not been given the same level of consideration. Collaboration with the members of the research team on this issue enabled Peter to realise that, without destroying the learning environment he had established, he could make changes in his teaching to provide more direction for students to learn the content of the physics lessons.

Assertion 2:

The teacher organized the content to be taught in terms of his knowledge rather than the knowledge presented in the textbook used for the course

At the outset of the research, Peter based his teaching around the textbook Fundamental Physics by Anderton (1985) which had been written by physics teachers in Western Australia for the syllabus for the Tertiary Entrance Examination. Another textbook by Murphy and Smoot (1974) was also used by the students. Observations made by the research team enabled Peter to become increasingly aware that in his individualized and student-centred classroom, the Anderton textbook did not allow the students to adequately learn concepts for themselves. There was universal agreement by the students that their textbook was difficult to use since: it contained too much information; was not to the point; was too hard to understand because it made too many assumptions about their previous knowledge; did not provide the answers to questions; and did not always give the required level of explanations. Students were learning physics despite the difficulties they were experiencing in gaining an understanding of the theory from their textbooks rather than because of the material in their textbook. Consquently, the interactions between the research team enabled Peter to use his own knowledge of the physics content to restructure the curriculum to help the students learn better.

In order to improve student understanding of the physics content of the lessons and to overcome what was seen as a limitation of the textbook for his style of teaching, Peter arranged for each student to be allocated from the school library one additional textbook to review. Students were given key words to help them focus on the various concepts in the topic to be considered and, since each textbook offered a different presentation of a given topic such as Vectors or Newtons Laws of Motion, students were required to summarise the major concepts of the topic in approximately three sentences. Subsequently, students were presented with a study guide which directed them to specific readings, exercises and laboratory experiments in their regular textbooks. Part of this study guide involved an activity sheet with suggestions organised in the way Peter believed was most appropriate for students to learn the content. For example, when dealing with Newton's First Law of Motion, the major objective, specific aims, key words and phrases, references and tasks to be completed were presented in the study guide. The first questions on the activity sheet were:

- Consider an object moving at a steady (constant) velocity along a frictionless surface (e.g. roller-skating can be considered almost frictionless). If no force acts on the object describe its motion.
- Try and summarise the above situation as a rule or a law (NO REFERENCE MATERIAL!!).
- Does your law make sense for an object that is stationary? Explain your answer.

These questions were designed to help the students develop their own ideas of Newton's First Law of Motion, given the knowledge they already had acquired from the initial readings of the alternative textbooks. In interviews later in the study, students commented on liking the activity sheets since they helped to provide a focus on the concepts to be learned and to quote one student "it helps to learn the ideas for yourself". However, a universal problem of the students was that there was never enough time to complete everything. As a result of the information identified by the research team on the manner in which students were learning the content, Peter used his own content knowledge to restructure much of the curriculum to enable students to better learn the concepts. He used sections of textbooks, specific worksheets and activity sheets to meet specific aims rather than have the students only work from the one textbook and the problem book without specific directions on what they were attempting to achieve.

In this reorganized teaching method of using textbooks students were processing the information in three different ways. They were attempting to understand key words and making their own overview, they were then re-using the material for the activity sheet and finally the test encouraged them to reproduce the material. This approach to learning would appear to be consistent with the constructivist model of knowledge as outlined by Bodner (1986), among others. Under the pressure of time, it would be possible for the students to reduce this to a single process by only working through the activity sheet. In this case, the activity sheet was something akin to students taking lesson notes without listening to a lesson.

The students reported that they were much happier with this approach than the previous approach. Students rated the activity sheet as a useful aid to understanding and were confident about their level of comprehension of the physics. Students also had a useful set of revision notes from this new approach which was better organized and more easily followed than their notes from the previous approach.

The difficulty experienced by students in understanding material directly from textbooks and the teacher's commitment to student-centred learning generated a study procedure which was most successful judged by student response, and which is supported by the constructivist model of learning. The teaching approach whereby students have more control over their own understanding of content has wide applications not only within a student-centred environment but in other situations where students are required to understand and learn from textbooks. In addition, students who have been exposed to a learning approach which encourages independent understanding of content in textbooks should be much better prepared for tertiary education than those who have unsuccessfully used their textbooks, since they will have improved their study and language skills.

However, there was a major problem with this instant use of research evidence from our collaborations: Peter believed that his increased awareness of the difficulties students were having with the arrangement of the content present in Anderton was requiring too much time for his preparation. He expressed the idea "that it would be better to have a folder with all study guides and activity sheets bound together and to be able to give them all to the students at the beginning of the course".

DISCUSSION

The initial aim of the study was to utilize a collaborative design involving a teacher-researcher and three university personnel to obtain information about the teaching of physics to Year 11 students, and specifically to identify and document the manner in which content knowledge is transmitted in the classroom and acquired by the students. However, the study became much more than the documentation of observations to be used to influence some future classroom practice. The teacher-researcher utilized the findings of the research as they were observed and interpreted on a daily basis and weekly basis. The two assertions emerged from the data and were not a priori hypotheses derived from theory or prior empirical investigations. The assertions provide an explanatory framework for Peter's reflection of his own practice of teaching and on the manner in which textbooks were used as the study progressed.

As was emphasised by Kyle & McCutcheon (1984), where collaboration takes place between teachers and researchers, each brings particular strengths to the study. Through the teacher's perspective, the research team had access to the insider's view of the classroom and enabled each member to gain valuable information about the teacher's philosophy, thought processes and attitudes. The teacher was able to offer explanations for events in the classroom observed by the outsiders and this in turn helped focus the study. The researchers were able to provide the teacher with added insights into the research process since they had a greater knowledge of research in education and were able to enhance the teachers' reflection on practice.

The two assertions do have relevance for other classroom teachers since the findings are generalizable to the science teaching community of teachers like Peter. Peter had a strong content background and a postgraduate qualification in science education. He was committed to providing a learning environment in which students could be responsible for and manage their own learning. He organized a physics programme which optimised knowledge of physics fundamentals and higher level cognitive skills. However, in adopting this style of teaching, Peter made assumptions about how students were obtaining information from the set textbook which was observed not to be entirely accurate.

An important aspect of this study was the finding that at the outset of the school year, students were not able to learn physics successfully from the set textbooks without considerable assistance. Peter's teaching approach was to initially give prime attention to the classroom environment and assume that the students were able to translate the physics in the texbook to scientific ideas that they understood. This study aided Peter in seeing that this assumption was incorrect and provided him with feedback to make modifications to his teaching which overcame the deficiency. Further, the students received these changes positively and commented on the improvement in their understanding of the physics being taught. In brief, this study, which used a collaborative design, would appear to have met the two goals recommended earlier by Watt & Wat (1982).

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RESULTS FROM THE SECOND INTERNATIONAL SCIENCE STUDY: SOME SEX DIFFERENCES FOR AUSTRALIAN 14-YEAR-OLD STUDENTS

Malcolm J. Rosier

INTRODUCTION

A basic introduction to the scope of the Second International Science Study (SISS) with preliminary international and national achievement scores has been provided in Rosier (1988). This brief paper sets out some information about sex differences in science achievement for the Australian sample of 14-year-old students, referred to as Population 2 in the reports of the study.

Structure of Tests

Each student completed a 30-item core test (Science Test 2M). In addition there were four 10-item rotated tests, included to increase the range of curriculum covered by the testing program. Each student took two rotated tests, assigned at random. Thus each student provided responses for a total of 50 items, although results were available overall for 70 items.

The main criterion science achievement score for each student is the Combined Science Test Score which is the sum of the score for Science Test 2M and the scores on the two rotated tests done by that student, with an adjustment for differences in the mean difficulty levels of the rotated tests.[1] Since this test is based on more items than the core Science test 2M, it offers students the opportunity to demonstrate their performance in science across a wider spectrum of the science curriculum. The test score is expressed as a percentage (referred to as the percentage score), obtained by dividing the score by the number of items in the test.

State Differences

The results of the study reveal that the mean science achievement of male students is generally higher than that of female students. The mean percentage score is 59.8 per cent for male students and 56.0 per cent for female students. The difference of 3.8 per cent is significant at the 95 per cent confidence level.[2]

The mean scores for male and female students by States are presented in Table 1. The mean score for males is higher than that for females in all States. The difference is largest in the Australian Capital Territory, and smallest in Victoria and South Australia. It appears that the large sex difference in the Austalian Capital Territory is due more to the rather high score for the male students than to low performance by the female students.

The standard error of sampling for the mean score of male students (or female students) within a State is higher than for all students in the sample for Australia overall since the sampling uncertainty increases as the sample size decreases. Although the pattern of differences indicates that male students obtain higher scores on average, the difference is significant at the 95 per cent level only for the Australian Capital Territory.

Percentage Frequency Distributions

The sex differences are primarily due to the better performance of male students at the higher score levels. It can be seen from the percentage frequency distributions in Table 2 that 4.8 per cent of the male students have a maximum score of 30 per cent. The corresponding percentage of female students is 4.7 per cent. However, 28.3 per cent of the male students have a score greater than 70 per cent, as opposed to only 18.5 per cent of the female students.

This pattern of differences between male and female students explains why the standard deviation for Australia overall is lower for female students. The distribution of scores for male and female students is similar on the lower part of the percentage frequency distribution, but there are more male students with higher scores at the higher end of the distribution. This has the effect of increasing the mean score for male students, and also increasing the standard deviation for male students. Suggested reasons for the sex differences will be explored later in this paper, when results for individual items will be discussed.

Although the above discussion highlights difference in mean scores, it is obvious from the results presented in this section that there are many individual female students with high scores, and that there are many female students with scores higher than the mean for male students.

Subject Scores

Table 3 presents scores for a range of subtests derived by different combinations of the 70 test items. In order to facilitate comparisons across subtests, which are based on different numbers of items, each test and subtest score is expressed as a mean percentage score.

It can be seen that the mean percentage score is higher for male students than for female students for each subtest, although not all of the differences are significant at the 95 per cent confidence level. The first four subtests refer to the major content areas covered by the tests. The difference in favour of male students is minimal for biology, but is significant for earth science, chemistry, and especially physics.

It was also possible to classify the test items in terms of teaching objectives: knowledge, comprehension and application. It is assumed that the items in these three objectives reflect increasing levels of cognitive functioning on the part of the students. The scores suggest that there is an increasing difference between the sexes as the level of cognitive functioning increases. The differences are 2.3 per cent for scores on the Knowledge Subtest, 3.5 per cent for the Comprehension Subtest, and 4.5 per cent for the Application Subtest. The latter two differences are significant. This suggests that the sex difference observed for the total science test mean score is partly due to the better performance of the male students on items calling for higher levels of cognitive functioning.

RESULTS FOR INDIVIDUAL ITEMS

This final section of the paper refers to a few specific items where there are major sex differences in the item percentage (the mean percentage correct for an item).

Items are referred to by their item number and by a short descriptive name.[3] Items are only included where the difference in item percentage between male and female students is higher than 10 per cent, which exceeds the criterion for a significant difference at the 95 per cent confidence level. There are no items where the female students score significantly higher than males.

The items are grouped by content areas, with an indication of the number of items in the subtest for each content area. This enables the relative number of items showing significant sex differences within the content area to be assessed. The summary at the end of the table shows the number of items by the categories of teaching objectives.

The majority of items showing major sex differences were physics items classified at the higher cognitive levels of comprehension and application. The summary across teaching objectives also demonstrates higher mean scores of male students for these higher cognitive levels.

NOTES

1. Details about the construction of the Combined Science Test Score are set out in Banks and Rosier (1989, in press).

2. The sampling design is a two stage disproportionate random sample. The estimates of standard errors of sampling referred to in this paper have been adjusted for the structure of the sample, and include allowance for the clustering of students in school groups.
3. A copy of the items is included in Banks and Rosier (1989, in press).

TABLE 1

Combined Science Test Scores for Male and Female Students by States

State	Mean % Score Male Students	Mean % Score Female Students	Difference Male - Female
ACT	69.7	59.9	9.8*
New South Wales	60.4	55.4	5.0
Victoria	57.1	54.4	2.7
Queensland	65.0	60.4	4.6
South Australia	60.0	57.5	2.5
Western Australia	64.4	60.0	4.4
Tasmania	61.2	55.7	5.5
Northern Territory	58.0	54.6	3.4
Australia	59.8	56.0	3.8*

Note: * indicates that the difference is significant at the 95 per cent level.

TABLE 2

Percentage Frequency Distribution for Combined Science Test

Band	Male	Female
Score 0	0.0	0.0
Score 1-10	0.1	0.2
Score 11-20	0.9	0.6
Score 21-30	3.8	3.9
Score 31-40	8.9	11.5
Score 41-50	17.0	19.9
Score 51-60	19.2	24.1
Score 61-70	21.9	23.0
Score 71-80	17.3	12.7
Score 81-90	9.6	3.5
Score 91-100	1.4	0.3

TABLE 3
Science Subtest Mean Percentage Scores

Test/subtest	Male	Female	Male-Female
Combined Science Test (50 items)	59.8	56.0	3.8*
Earth Science Subtest (9 items)	68.1	64.8	3.3*
Biology Subtest (23 items)	59.3	58.0	1.3
Chemistry Subtest (15 items)	49.5	46.1	3.4*
Physics Subtest (23 items)	65.0	58.9	6.1*
Knowledge Subtest (19 items)	58.7	56.4	2.3
Comprehension Subtest (24 items)	60.0	56.5	3.5*
Application Subtest (27 items)	61.6	57.1	4.5*

Note: * indicates that the difference is significant at the 95 per cent level.

TABLE 4

Item Percentages With Large Sex Differences

Subtest/item	Teaching Objective	Item Percentage		
		Male	Female	Male-Female
Earth Science (9 items in subtest)				
Rocket Ship to Moon	Knowledge	73	61	12
Facing North	Comprehension	67	57	10
Why Can We See The Moon	Application	75	64	11
Biology (23 items in subtest)				
Insect C02 Apparatus	Application	39	28	11
Chemistry (15 items in subtest)				
Melting Points of Elements	Comprehension	67	57	10
Physics (23 items in subtest)				
Magnifying Glass	Knowledge	58	37	21
Thermometer For Body	Comprehension	64	54	10
Pivoted Rod	Comprehension	54	43	11
Flashlight Batteries	Comprehension	91	79	12
Bounce Rubber Balls	Application	84	73	11
Objects On Thread	Application	35	20	15
Spaceships Communicate	Application	73	56	17

Summary of Objective

Knowledge items: 2 items out of 19 items in the subtest.
Comprehension items: 5 items out of 24 items in the subtest.
Application items: 5 items out of 27 items in the subtest.

Total items: 12 items out of 70 items in the test.

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COUNTERING FUNDAMENTAL MISCONCEPTIONS ABOUT LIGHT

AN ANALYSIS OF SPECIFIC TEACHING STRATEGIES WITH YEAR 8 STUDENTS

Tony Fetherstonhaugh and John Happs

INTRODUCTION

A comparative study of prevalent student understanding about light (Fetherstonhaugh et. al. 1987) indicated how secondary and tertiary students from Western Australia, France, New Zealand, Sweden and the United States held similar misconceptions in terms of how light travels and interacts with mirrors and lenses and how we are able to see objects. A secondary aim, following on from this comparative study, was to use the central misconceptions about light in the design and implementation of specific teaching strategies which might better address some of those misconceptions held by students.

This paper describes part of an on-going study that monitors some misconceptions about light as found in one class of year 8 students at a Western Australian secondary school. Additionally this paper discusses the learning of a small group of students within that class as it interacted with the teaching program dealing with light.

Developing appropriate teaching strategies

Teaching modules used in this study were developed along lines suggested in the model proposed by Posner et. al. (1982) which suggested four conditions for concept replacement and the following scheme:

(a) Spend time diagnosing errors in student thinking.
(b) Develop strategies to deal with errors.
(c) Develop procedures that create conflict.
(d) Track the progress of conceptual change.

A series of lessons was planned to address and counter some of the main misconceptions about light (6 x 45 minutes). Only the first two lessons are discussed here since it was considered that some of the fundamental misconceptions about light were challenged during those initial lessons.

Diagnosing errors in student thinking

The questionnaire designed to elicit student views about light is documented in Fetherstonhaugh and Happs (1988). This instrument was given to the monitored year 8 class towards the end of 1987.

Summary statistics for the responses provided by the year 8 students (N=20) are given in Fetherstonhaugh and Happs (1988).

Distance travelled by light

The first two questions probed student understanding of how light travels and, as found with previous students, a significant number believed that light does not travel at all or travels variable distances. The majority (66%) felt that light will travel until it strikes an object. The number of students who considered that light from a light bulb travels until it hits something when the light is switched on at night increased markedly (81%). Their reasoning was based on bright light being stronger and therefore capable of travelling greater distances at night. Light from the sun was seen to suppress the movement of "weaker" light. Many students (74%) considered that light from a car's headlamps will only travel about 400m or as far as the person looking at the headlamps. Individual interviews with students in the group being monitored probed their understanding of light behaviour as a fluorescent tube was switched on. Paul was convinced that the light would tend to remain on the tube during daylight hours and he explained this in terms of light from the fluorescent tube not being strong enough to compete with daylight:

P I think the light will stay in the tube, on it, —.
I Why is that?
P Cos the light outside is enough to keep the light inside and the light in there (points to fluorescent tube) is not as strong as the light out there.

Sharon initially considered that light from the fluorescent tube would "go outside the room so far until it hit something".

This latter comment was qualified when specific distances were mentioned:

I Would it (light) hit those poles out there? (100m distant).
S Oh, I suppose - no I don't think so.
I You don't think it would go that far?
S Oh no I don't think so.
I How far do you think it would go?

S Probably as far as those small trees.

I About 10m?

S Yep.

Brendon appeared to hold a scientific perspective of light propagation in that he felt that light from a fluorescent tube would travel outwards until it hit an object and then the light might well be reflected onto another object. He also considered that the day-night factor did not influence the distance the light would travel:

I Does it make any difference if it's night time?

B I don't think it would make any difference.

Light is necessary for vision

Items 8 and 9 in the questionnaire probed student understanding about light being a necessary condition for animals to see and the majority of year 8 students (78%) considered this to be true for humans yet 52% reported that in a completely darkened room a cat would be able to see an object quite clearly.

The question of how we see objects was pursued and this seemed to be an area of some difficulty:

P umm — Well it's (light) lighting it up so we can see it cos when it's dark you can't see them (trees) and it (light) helps your eyes to look at it (tree).

A better, although not convincing, explanation of how we see objects came from Sharon:

S The light hits the tree and comes back and we can see it I suppose, I don't know.

The idea of eyes "looking" at objects implies that some seeing rays are leaving the eyes, to strike the object being seen.

Although there was no specific question on the survey to probe student understanding about "seeing rays leaving the eyes" approximately 90% of the year 8 students involved in this investigation (assessed by show of hands in response to the teacher's question) felt that something did leave the eye when looking at objects and the sensation from such a "ray" could be felt if someone behind stared at you for a few seconds. Amongst the numerous misconceptions identified by the questionnaire were the following:

1. Light doesn't travel at all.
2. Light travels differently during the day and night.
3. We see by looking at objects, i.e. the visual ray idea.
4. People can just see in total darkness when their eyes become adjusted.
5. Cats can always see in total darkness.

This paper focuses on ways in which some of these misconceptions were addressed.

Countering fundamental misconceptions about light

The first lesson started with students being given question sheets on light with preliminary questions about the behaviour of light being answered firstly, e.g.

1. Write down how you think we see an object such as the pen that you are holding?
2. What must light do before we can see? If there was no light do you think we could see?

Students were directed to answer only questions 1 and 2 initially so that a discussion and summary of their ideas could be extracted prior to the teacher's explanation of the scientists' model with some of the exposed prevalent views.

Responses to the question about how we can see an object (question 1) were mixed although it became apparent that several students answered the question in terms of something leaving the eye to strike the object and many students made explicit their opinion that it was possible to stare at a person's back and have that person "feel" the stare.

Mixed responses were also obtained for questions dealing with seeing in the dark and the need for light to reflect off objects into our eyes with significant numbers of students commenting that eyes can get used to seeing in total darkness. Students expressed views were summarised before the teacher provided information on the scientist's model of how we see and student responses were neither rejected nor readily accepted at this stage since comparisons of the various perspectives were sought later on.

The teacher started to summarise the scientist's model of how we see after pointing out to the class that this particular model would be very similar to some of the ideas already proposed by class members. The following points were made:

- To be able to see we need to have light.
- You can't see in total darkness.
- Light will bounce off an object and enter your eyes.
- At the back of the eyeball (retina) there are millions of nerve endings which send messages to the brain about the shape and colour of the image seen.

These points were recorded by students and a discussion ensued so that comparisons of childrens' views and scientists' views about light were made clear.

Following this discussion the class was asked to move on to other questions on their handout so they might use the views about light as expressed by their peers and the summarised scientist's model.

The class was told that they were shortly going to enter the school's darkroom and that no light could enter that room when the doors were closed and all lights turned off. Students were asked to predict whether or not they would:

- Clearly see objects
- Partially see objects
- Only just see objects when eyes become adjusted to darkness
- Cannot see objects.

At least one third of the children expressed the opinion that they would probably be able to make out objects when all the lights were turned out in the darkroom and the idea of eyes getting "used to the dark" was mentioned by several class members.

A visit to the darkroom

It became clear that the majority of these year 8 students had never experienced total darkness either in rooms such as the school darkroom or in caves, mines, etc., and the class had to experience total darkness for several minutes before there were comments of conviction that they could not even see a hand in front of their face. Initial responses from some of the students suggested that they could still "see" shapes of heads and hands and this was explained in terms of the image of a light filament remaining active on the retina after the light bulb has been extinguished. The teacher turned the lights down and asked students to say what he was holding in his hand. A pen was held up at this point and when the room was in total darkness some of the students still imagined that they could see the pen that the teacher had held up previously despite the fact that the pen was not being held up at this stage.

The question was asked:

"A lot of people think that cats can see fairly well when it is totally dark — if we had a cat in a room such as this — what do you think about the cat now? Do you think it would be able to see if there was no light?"

Many class members answered in unison "NO".

When the question was asked:

"Do you think cats need light to see?"

The response was not convincing in that a few students were still emphatic about a cat's ability to see in total darkness.

The teacher explained that cats have eyes which can operate at a lower level of light so they can easily find their way around at night by the light from the moon and stars.

Students returned to their classroom and ideas about humans and cats needing light to see were summarised along with the observations in the darkroom. At the end of this recording period the teacher asked the class:

T Who thinks it would be possible to see things with absolutely no light?

None of the students raised a hand.

T Well what is the difference between human eyes and cats eyes"

One student volunteered "no difference" to which the teacher countered:

T Well if there is no difference, how do you think cats would be able to see when the light is very very dim?

S1 Their eyes are more sensitive than ours.

S2 They (cats) would be more used to it (dark) walking around in the dark.

A murmur of concurrence with this response came from two of the students in the group being monitored and Sharon directed her (similar) thoughts to others in the group:

S Cats might just get used to wandering around in the dark and seeing. The investigator suspected at this point that not all the students in the class were convinced that all animals (with eyes) require light to see objects despite apparent group unanimity of response indicating views to the contrary. The Lamarkian idea of cats' eyes improving as they got used to the dark may be very common amongst adolescents and adults. The second lesson was designed to address the miconception initially expressed by at least 90% of this particular year 8 class, that something did leave the eye when objects were being observed such that the sensation from a stare could be felt by individuals.

It was put to the class that some people considered the above statement to be true and individuals were asked to record their own views on the matter. Group discussion was encouraged on this point and the second investigator monitored the comments that were forthcoming from Paul, Sharon, Brendon and Susan. The investigator made the initial comment:

I I've heard people say that if I stare at somebody - - -I've heard people say that if I stare hard enough at a person in front of me they'll eventually turn round because they feel that I'm looking at them.

Susan immediately responded with "yes" and Brendon sad "It's like a sixth sense".

The conversation continued:

I Do you think that's possible Sharon?

S Well if people stare at you, you are sort of urged to turn around.

I Do you think it's possible then - to feel someone looking at you?

S Yes.

Paul wasn't too sure whether you could actually feel a stare or not, yet it quickly became apparent that the majority of these year 8 children were convinced that a stare could be felt.

Susan suggested an awareness of an observer:

S You know that they are looking at you but you don't actually feel anything do you?

Paul was sure that he could feel a stare from someone.

The students were asked about the possibility of something leaving the eye when a person was staring at an object or person:

T What do you mean when you say you actually "see them" - do you do something with your eyes to see them or is the light doing something to your eyes?

(Brendon and Paul) "both"

Discussion with this small group revealed that the idea of light entering the eye for "seeing" to be achieved appeared to be accepted alongside the emitted ray notion:

P You still have to look at an object.

One class member stated that to see an object more clearly you have to look at it harder and a number of others in the class concurred with this view.

The teacher then posed the question specifically to the class:

T People often say "I felt someone looking at me — how many people have noticed that — how many people have felt someone looking at them?

Eighteen students (90% of class) raised their hands in acknowledgement of this experience and at this stage the class was asked to devise, in groups, an experiment which might determine whether it was true or not about people being able to feel someone staring at them.

Class groups were invited to select a spokesperson to summarise their experimental design so that the best one might be used as a whole class investigation.

Testing a Misconception

Students were distributed in a semi-circle with a recorder in the centre and a randomly selected "starer".

Students in a semi-circle were asked to turn away so that they couldn't determine who was being stared at. Only the recorder was told (via a whisper) who was being stared at and after one minute of staring students were asked to indicate if any of them actually felt a stare. Usually 3 or 4 students stated that they had felt the stare yet after several attempts by the same starer none of the students being stared at was able to tell. The experiment continued using 10 different starers and the results were such that all students concluded that it was impossible to feel a person staring at them.

Post-teaching Understanding About Light

Three months following the teaching programme on light, the year 8 class was given the same "multiple choice plus reasons" questionnaire. Additionally Paul, Sharon and Brendon were individually interviewed again in order to better assess the impact of the teaching program on their initial misconceptions.

The class had undergone a marked improvement in apparent understanding of light and key misconceptions generally seemed to have been lowered in number (see Fetherstonhaugh and Happs, 1988).

More specifically it was found (via interviews) that Paul, Sharon and Brendon had undergone marked improvements in the way their misconceptions about light had been successfully challenged. In terms of how these 3 students perceived the propagation of light from a fluorescent tube, none of them had reverted to a consideration of the day-night factor and sunlight being strong enough to keep the fluorescent light on the tube. Paul and Brendon were both satisfied that neither a person nor a cat would be able to see in a totally dark room yet Sharon appeared to vacilate over the possibility of nocturnal animals being able to see objects in total darkness. She was ultimately able to arrive at the correct idea when she called upon the appropriate framework, i.e. light is necessary for seeing.

DISCUSSION

Our earlier comparative study into student understanding about aspects of light (Fetherstonhaugh et. al., 1987) revealed a number of prevalent misconceptions which appeared to be paralleled worldwide. Attempting to address all identified misconceptions in this area required extensive and repeated trialling of teaching strategies. Much of this work has been documented in Fetherstonhaugh (1988).

This paper has considered our response to those few misconceptions which are likely to influence student learning outcomes in the early stage of any teaching programme dealing with light. The investigators felt that misconceptions about how light travels and how we see objects should be targetted at an early stage since students' later acquisition of knowledge will most likely be influenced by any non-scientific perspectives they may hold about the behaviour of light and eyes.

Notions such as:

- Light does not travel at all.
- Light travels further at night.

- Cats can see in total darkness.
- People can get used to seeing in total darkness.
- Something leaves the eye when we stare at objects.

were prevalent and although post-testing outcomes suggested a significant decrease in student misconceptions in these 5 areas, individual interviews leave us feeling unconvinced that all students who appeared to have changed their thinking will permanently relinquish their misconceptions about light and how we see.

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BEING COOL IN THE COOL UNIT
OR
EVALUATING THE LEARNING OF REFRIGERATION FROM SCRATCH

Barry Newman, Mark Cosgrove and Mike Forret

Learning to design your own refrigerator, trying to understand how and why one works and finding that your teacher won't tell you, could be a little disconcerting. Not being all that interested in the topic to start with, feeling that as a female it was beyond you, recognising that you'd been quite successful learning physics by the old method or not being all that good at physics anyway, wouldn't seem to help either. What's it really like?

INTRODUCTION

A unit on refrigeration was designed for the teaching of New Zealand sixth form physics students. The approach adopted by the unit is characterised partly by the interactive teaching model developed by Biddulph and Osborne (1984), a model based upon a generative learning theory (Osborne and Wittrock, 1985) and partly by an assumption of the usefulness of teaching science through technology. A description of the unit is to be found in Working Paper No. 211 (Cosgrove and Mueggenburg, 1986), S.E.R.U., University of Waikato - Hamilton Teachers College. Working Paper No. 212 (Newman, 1986) of the same establishment is a report on its evaluation. A paper detailing the underlying assumptions of the unit and outlining some of the findings from the evaluation was presented at an international symposium on science and technology education (Cogrove, Newman and Forret, 1987). What is reported below is a more detailed description of the evaluation process and findings together with some reference to a replicating study carried out one year after the original.

TEACHING THE UNIT

The unit as taught had a number of stages. Students viewed a video on the use of refrigeration, raised some questions about refrigeration, made "before statements" on how they thought a refrigerator worked, interacted with some practical activities, discussed the subject with their peers and teacher, interviewed an "expert", experienced a slide/tape presentation on the subject, design a refrigerator and made "after statements" on how they now thought a refrigerator worked.

While the slide/tape segment dealt with heat and its connection with refrigeration neither the "expert" nor the teacher involved indicated how refrigerators worked. The unit was characterised by students having to create their own understanding with little feedback given by "expert" or teacher.

The unit was taught over 9 periods to 53 students (36 males, 17 females) in 3 classes, two teachers participating. The replicating study involved 35 students (23 males, 12 females) in 2 classes, one teacher being involved.

EVALUATING THE UNIT

There were three major components to the evaluation. During the unit informal observations were made of teacher and student activity and informal interviews were carried out with students. At the end of the unit a questionnaire was given to 45 students (28 male, 17 female). Thirdly, statements made by students at the beginning of the unit (43) and 4 weeks after the unit (47) on how a refrigerator works, were analysed. No notice was given in either case of such a statement being required.

The replicating study involved a different evaluator and brief reference only, will be made below, to some of its findings.

RESULTS

Some gender differences on a number of measures were observed and these are reported in Table 1.

Observations and Interviews

1. Students' Misconceptions

Observations and interviews revealed a number of "misconceptions" which students brought to their understanding of the practical activities of the unit or which arose during the activities. Some of these beliefs carried over into their understanding of how a refrigerator works and some persisted throughout the unit. For example, at least one student thought that in order for acetone to evaporate air was necessary. Another student believed that freon in a can was cold because it had been liquified and liquified freon was very cold. Some thought that where there were temperature changes perhaps endo-and exo-thermic reactions were involved. Friction was appealed to by a number of students to explain why a gas became hot under compression. At least one student believed that because the activities with thermostats only involved heating, deformation by cooling would be difficult.

2. Appraisal of Practical Activities

A critical appraisal of the practical activities could be made on the basis of an examination of their nature together with what students had to say of them and the way they interacted with them. For example, a wet and dry bulb thermometer activity, designed to illustrate that as water evaporates the temperature drops, was confusing because of its association with the measure of humidity. Dismantling a refrigerator was helpful to some of those actively engaged in the dismantling but not for those who were not. An activity of examining a working refrigerator was engaged in by only few students, perhaps because of its inconvenient location and because of its familiarity. In a bicycle pump activity the only measure of an increase in temperature of compressed air was the temperature of the pump barrel itself; it was then questionable whether this was due to any increase in the temperature of the air. There was no activity where a gas was compressed to a liquid, with a consequent rise in temperatures; understandably, that aspect of refrigeration was generally omitted in statements on how a refrigerator works.

3. Students' Views on the Unit

During the unit students were encouraged to indicate what their views were on what they were doing. During the activities section, one student stated: "It's a good way of helping us to understand the very technical" while another exclaimed: "You wouldn't want to be a person who gave up easily in this exercise". During the design stage, one male indicated that the unit neither attracted nor bothered him, while another felt it could get a bit boring. One group of females upon being asked "Is this too tough?" replied "Yes, it sure is!". One female, experiencing difficulty in getting started, believed that maybe she didn't think logically enough.

THE QUESTIONNAIRE

1. The Practical Activities

Two questions dealt with how the students perceived each of the practical activities - their interest in them and the help they thought they received from them. An activity with thermostats, another involving the dismantling of a refrigerator and a third involving the use of freon gas were regarded as being among the most interesting. The freon activity was also the one that most students thought was the most helpful.

There were some gender differences relating to the perceived helpfulness of two of the activities - see Table 1.

A similar profile of, interest in and perceived help from, the various activities, was obtained in the second study.

TABLE 1
Some Gender Comparisons from Study 1

A. QUESTIONNAIRE ANALYSIS	% Male	% Female
Mentioning dismantling a refrigerator as an activity that helped understanding ...	43	6*
Mentioning using freon as an activity that helped understanding ...	46	82*
Claiming interest in how a refrigerator works before the start of unit ...	36	0*
Claiming to have ideas on the operation of a refrigerator before the start of the unit ...	57	18*
Claiming to have ideas on the operation of a refrigerator during the audiovisual segment ...	25	65*
B. AFTER STATEMENT ANALYSIS		
Making satisfactory after statements...	33	70*
Of those making satisfactory after statements those using one or more diagrams...	80	17**
Of those making satisfactory after statements the average number of words used ...	77	127***
C. END-OF-YEAR PHYSICS EXAMINATION		
Mean % performance on the examination for all students involved in the study ...	58.3	55.3 NS
Mean % performance on the examination for those making after statements ...	59.2	56.6 NS
Mean % performance on the examination for those making satisfactory after statements ...	62.9	59.8 NS

* statistically significant at the 5% level using a ^{2} test with a Yates correction.
** statistically significant at the 2% level using a ^{2} test with a Yates correction.
*** statistically significant at the 2% level using a Cochran and Cox t test.
NS not statistically significant at the 20% level using a Cochran and Cox t test.

2. The Stages of the Unit

Three questions dealt with interest and ideas before working on the unit and then at the various stages of the unit. No female and only 36% of males claimed interest in the subject before the unit started. A majority of students indicated that it was while they were working with the practical activities and designing their own system that they were interested in how a refrigerator works. These aspects of the unit together with that of working with the expert and interacting with the class as a whole were also mentioned by a majority as those when they had some ideas on how a refrigerator works. In addition to these elements, a fifth - interacting with one's peers, was cited by a majority as being those when they put some of those ideas together.

Some gender differences relating to two of the questions are referred to in Table 1.

The overall profiles obtained in both studies for these three questions were, again with few exceptions, found to be very similar.

3. Student Attitudes, Confidence and Perceived Understanding

Two questions were directed at the students' attitudes towards the unit as a whole. 61% claimed they liked the unit either a reasonable amount or a lot, while a further 20% claimed they liked it a little. When asked to compare the approach of the unit in teaching physics with "the usual way physics is taught" 51% claimed they liked the approach of the unit better, with 13% claiming the reverse.

One question dealt with how confident they felt while working through the unit. Only 7% reported that they did not feel all that confident, while 44% claimed to feel reasonably confident. The remainder claimed that they felt O.K.

As regards their understanding on how a refrigerator works, 93% claimed, at the end of the unit, that they thought they had a reasonable understanding or greater.

4. Students' Free Response Comments

Most students made comments in a free response section of the questionnaire. A number of students referred favourably to the methodology of the unit with statements such as: "This unit helped you to develop ideas in your own words without somebody telling you (and this) gave you a greater understanding" and "I really enjoyed trying to find out for myself how a fridge works; now I will remember it much clearer than other things I have been taught". A few students, all who liked the usual approach to teaching physics better, made negative remarks about the methodology. For example: "The questions we formed during the unit were usually not answered and that left us nowhere. It kept us off balance and most of the time we worked out wrong solutions" and "I thought that it took too long to find out the answers about fridges".

BEFORE AND AFTER STATEMENTS

When asked to make a statement at the beginning of the unit on how a refrigerator worked, 23% claimed they didn't know and made no further statement. In general, "before statements" were sketchy comments involving some mention of heat and various refrigerator components. "After statements", with far more detail, had descriptions that incorporated closed cyclical systems involving liquid to gas to liquid changes with references to transfer of heat between various entities, transfer of heat from inside the refrigerator to outside, and notions of expansion and compression.

"After statements" were credited as being "satisfactory" provided they were not deficient in more than a few significant features of a "good" explanation. On this basis 47% of the statements were designated "satisfactory". It should be borne in mind that the task of providing these statements was given four weeks after the completion of the unit and without notice. Those statements regarded as satisfactory were analysed for gender differences - see Table 1. A higher percentage of females than males made satisfactory statements and the females making such statements used more words than males. More males than females used diagrams. These gender differences were not confirmed in the second study. Part of the explanation for this discrepancy could be due to the use of two different evaluators. Furthermore some changes had been made to the unit on the second occasion as a result of the findings gathered on the first.

The students' performance on an end-of-year physics examination was also analysed for gender differences for all students involved in the study, for all those making after statements and for all those making satisfactory after statements. No significant differences up to the 20% level were found. Details are to be found in Table 1. Using a Cochran and Cox t test no significant difference up to the 20% level on examination performance was found between all females making after statements and all females making satisfactory after statements. The same was true for males.

DISCUSSION

The evaluation would appear to be valuable in terms of giving suggestions on how the unit could be improved. For one thing, it highlights the plausible. Activities that don't clearly relate to refrigeration are likely to result in confusion and the absence of activities related to principles of refrigeration is likely to result in those principles not being understood. It also enables the teacher to see what facets of the unit students perceive to be helpful and interesting.

Hawthorn effects were almost certainly operating during the unit. This aside however, the unit with its interactive teaching components, its generative learning theory underpinnings and its science in technology perspective could not be judged to be a failure. In terms of students' perceptions of their understanding at the end of the unit, their view of the methodology of the unit and the statements they made on how a refrigerator works, four weeks after the unit, the unit was more like a success than a failure.

Of some interest is the finding that, based on the performance in the end-of-year physics examination, the females who were able to make adequate statements on the working of a refrigerator were approximately representative of all females making such statements, adequate or otherwise, the same being true for males. Does the methodology of the unit favour reasonably equally the scholarly and the less scholarly?

Perhaps of most interest are the gender differences. That females performed better than males in a senior physics unit, in the first study (and no worse in the second) is worthy of note. Did the females "work harder", because they were less interested before the unit began? Were the females choosing physics more mature than their female peers? Did they act more responsibly and with less warranted confidence than the males? Did the autonomy given to students in the unit favour the females rather than the males?

Whether females or males however, students, need to be considered as individuals. It is one thing to assert that a majority of students liked the unit and that most thought they had a reasonable understanding of how a refrigerator works at the end of the unit. It is another to realise that some individuals had no confidence that they had worked out the principles of refrigeration or preferred by far, the usual method of teaching physics. What is suitable for Jack and Jill is not so for Jean and John.

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LEARNING IN SCIENCE: QUALITATIVE AND QUANTITATIVE INVESTIGATION IN YEAR 10 CLASSROOMS

Barry J. Fraser and Leonie J. Rennie

INTRODUCTION

Because of a discrepancy between what we felt ought to be happening in science classrooms and what appeared to be happening, a study was planned to investigate teaching and learning processes associated with student acquisition of high-level cognitive learning. Research indicates that the types of activities prescribed by the teacher often constrain the opportunities that students have for high-level learning during class time by placing them in situations in which they listen to the teacher or a peer, copy down notes or work from the textbook. Indeed, the learning environment provided in most high school science classes seems to be the antithesis of a constructivist theory of knowledge acquisition (e.g. Pines & West, 1986).

This paper reports parts of a comprehensive study in which six researchers intensively investigated two science teachers for a period of 10 weeks (Tobin, Fraser & Kahle, in press). Although the main focus of the study was on teaching for higher-level cognitive learning, the difference methods and elements of the study blend together to provide a composite picture of various aspects of teaching and learning in science classrooms. One of the strengths and distinctive features of the study is the range of both qualitative and quantitative methods used for collecting and interpreting data. The study illustrated how and why teachers structure their learning environments in certain ways and what values and goals were held by teachers.

METHOD AND DESIGN OF RESEARCH

Two science teachers, Sandra and Peter, from the same urban high school in Western Australia participated in the study. The school was selected because of its tradition of emphasizing student-centred, self-paced learning. These teachers had taught science for approximately ten years and were regarded by their colleagues as successful. Both taught an advanced/intermediate Grade 10 class. Peter's class contained 11 boys and 20 girls, whereas Sandra's class consisted of 14 boys and 17 girls.

The teaching component of the study took place over a 10-week period from approximately August to November of 1986. Both teachers taught the topic of Vertebrates during the first five-week period and the topic of Nuclear Energy during the second five-week interval, with a period of two weeks separating the two topics.

For the first topic, five of the researchers observed each teacher for a minimum of six lessons. Virtually all of the approximately 20 lessons were observed by at least one and usually two of the researchers. During the second topic, each member of the research team gathered data appropriate to one of the following specific foci: gender-related differences; the cognitive developmental level of the students and the extent to which they understood the content; student perceptions of the learning environment; students' attitudes and the extent to which they engaged in learning tasks; and the manner in which the teacher implemented the program.

Interpretative research methology (Erickson, 1986) and participant observation were employed. These involved observing classrooms, interviewing teachers and students on a daily basis, working with students during class time, obtaining written responses to specific questions, examining student notebooks and test papers, and considering teacher assessments of student performance. During interviews, the teachers were allowed to speak without interruption, and every attempt was made to avoid leading questions.

As the study progressed, the research team made decisions about the aspects of teaching and learning on which they would focus, the data which were to be collected, and procedures to be adopted in collecting and validating data. Care was taken that data were obtained from a variety of sources and that multiple perspectives were represented in the data obtained from researchers, teachers and students. As soon as possible after each lesson, all data were compiled into written field notes which were circulated among members of the research team. Team meetings were scheduled three times a week prior to visits to the school mainly to discuss the data and their interpretations. On the basis of the results, data collecting strategies were formulated with the intention of gathering additional data to support or refute assertions. Each teacher was provided with written reports of the study and the findings, and feedback from the teachers on the reports was used as another data source.

Background Information About Teachers and School

Peter was an enthusiastic teacher who was keen to establish himself at the school (which we refer to as Southside High). As a result of his teaching experiences at two other Western Australian schools and in Canada, Peter had honed a confident teaching style.

Yet the move to Southside High imposed some constraints on the manner in which Peter was able to teach because of its tradition of being an open school. The school's adoption of a self-paced style of presentation based on student use of workbooks constrained the curriculum in a manner which frustrated many of the current staff, including Peter. Peter emphasized field trips and encouraged his students to be involved in a variety of excursions. Also, he often volunteered to drive the school bus and he organized a lunchtime science competition in conjunction with School's Science Week.

Sandra had a background of employment which included periods of working as a scientist and teaching in three states of Australia. Her experience teaching in two separate school systems before coming to teach in Western Australia involved different curricula and varying amounts of curricular autonomy. At the time of the study, Sandra had been teaching high school science for 10 years. She was head of department at Southside High with responsibility for lower secondary science and biological sciences.

When Southside High commenced in 1977, student independence and individual decision-making were valued highly. Students were allowed to learn at their own rates and to study science topics in which they were interested. Also students were responsible for their own time-keeping and there were no sirens or bells to signal the end of class time. The staff set out to establish a relationship in which teachers and students were partners in learning (e.g. the first name basis on which staff and students addressed one another). Although foundation staff identified strongly with the approach, few new teachers were committed to it. The most notable aspect of the student-centred approach that remained was use of the workbooks which were used in both classes and for both topics in our study.

The classroom in which Peter taught was separated by a movable partition from Sandra's room which was adjacent. Unlike the early days of team teaching at Southside High, the concertina walls separating these two classrooms remained shut. The sound that penetrated this partition often was distracting, and a normal-size blackboard was not available at the front of the room because of the partition. Peter's room consisted of benches arranged in six rows like a conventional science classroom. Peter claimed that he did not like the arrangement but, because he only taught this one class in the room, he was ruluctant to rearrange the furniture and possibly inconvenience other teachers. In Sandra's class movable rectangular tables were placed together in pairs to make larger rectangular seating units which enabled four or five students to work at the table in a group.

RESULTS

Teachers' Beliefs and Metaphors

The teachers' beliefs about their roles appear to have had a strong influence on the way the curriculum was implemented. Sandra afforded greatest value to her role as facilitator of learning. These beliefs were clearly articulated in a repertory grid analysis, in interviews with Sandra and in her teaching. In contrast, Peter gave greatest emphasis to his role as a manager in the classroom. During interviews and as Peter implemented the curriculum, his efforts to assert a strong influence on what happened in the class were clearly evident.

During interviews, Sandra described her main role in terms of being a "Resource" to assist students to learn with understanding. Her efforts to share that resource equally between the students in her class were always evident as she moved continuously around the room and dealt with groups or individuals for the great majority of the allocated time. In contrast, interviews with Peter suggested that he conceptualized his role in terms of two metaphors, the "Captain of the Ship" and the "Entertainer", and the lessons varied greatly depending on which metaphor he used.

As well, Peter projected a "macho" image which might have been associated with the outdoors type of person he preferred to be. When he interacted with males in the class, he made efforts to be "one of the boys" and when he interacted with females he sometimes made suggestive remarks associated with the students as females, not science students.

Perceptions of Classroom Environment

The field of classroom environment and range of measuring instruments are reviewed comprehensively in Fraser (1986a, 1986b). In this study, use was made of selected scales from the Individualized Classroom Environment Questionnaire (ICEQ) (Fraser, 1989; Rentoul & Fraser, 1979) and the Classroom Environment Scale (CES) (Moos & Trickett, 1987; Trickett & Moos, 1973). An important feature of the design of the present study was that these classroom environment dimensions were selected after a certain amount of field work had been done and, consequently, only dimensions considered to be salient were selected for inclusion in the research. For the purposes of the present study, the four scales selected as salient were Personalization and Participation from the ICEQ and Order and Organization and Task Orientation from the CES.

ICEQ scales each contain 10 items with the five response alternatives of Almost Never, Seldom, Sometimes, Often and Very Often. Students responded to both the actual and preferred forms of each scale after the teaching of Vertebrates and answered the actual form again after the teaching of Nuclear Energy. For the two 10-item scales from the CES, the original two-point (True, False) response format was changed to the same five-point response format as teh ICEQ (Almost Never, Seldom, Sometimes, Often, Very Often). Although item wording is almost identical in actual and preferred forms, words such as "would" are included in the preferred form to remind respondents that they are rating preferred environment. For example, the statement "This is a well-organized class" in the actual form of the Order and Organization scale would be changed in the preferred form to "This would be a well-organized class". For large samples of over 100 classes, alpha reliabilities for class means ranged from 0.72 to 0.90 for the actual form and from 0.65 to 0.86 from the preferred form (Fraser, 1986a).

Figure 1 depicts the profiles of mean actual classroom environment scores obtained by averaging the individual scale scores of the 31 students in Peter's class and the 31 students in Sandra's class. These profiles have been constructed separately for the first topic of Vertebrates and for the second topic of Nuclear Energy. Figure 1 clearly shows that the two greates student-perceived differences between the teachers for both topics were that, relative to Peter's class, Sandra's class was characterized by considerably more Personalization and less Order and Organization. Moreover, two-way analyses of variance with class and gender as independent variables revealed that differences were significant at the 0.01 level of confidence for Personalizatin and Order and Organization for both topics. All other differences were nonsignificant, with the exception that Sandra's class was seen as having significantly more Task Orientation than Peter's class for the second topic of Nuclear Energy.

Another question investigated was whether students perceived their classrooms differently during the teaching of the two topics. This was interesting because the researchers had fed back information from the first administration of the classroom environment scales to the teachers, and there was the possibility that they might have used this information to stimulate and guide improvements in their classroom environments. Although the changes in classroom environment occurring between the two topics are not large, the profiles in Figure 1 still reveal some interesting and consistent patterns. First, Peter's classroom environment was less favourable for the second topic than the first on all scales except Order and Organization (for which the difference was negligible). On the other hand, Sandra managed to improve on all four dimensions between the two testing occasions.

The patterns in Figure 1 are consistent with the fact the two teachers differed markedly in their reactions and responsiveness to receiving from the researchers feedback information based on classroom environment results for the previous topic of Vertebrates. Sandra was interested and concerned with this feedback and was determined to change her classroom behaviour in ways which would lead to improvements in classroom environment. On the other hand, Peter dismissed the classroom environment information from the previous topic as irrelevant and made no attempt to change behaviour. For example, Peter disbelieved the feedback that suggested that students perceived a relatively low level of Personalization in his classroom because he felt that his attempts to entertain the students through his singing, quips, etc. (i.e. the Entertainer metaphor) would be associated with high Personalization. Although Peter was keen about covering the content and being entertaining, he did not attempt to enhance classroom Personalization as a way of aiding student understanding of the content.

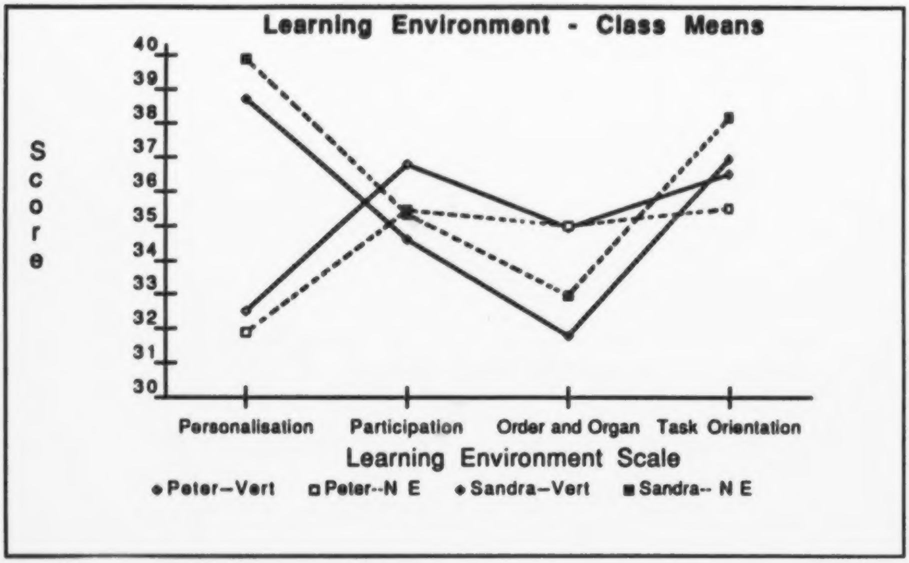

Figure 1: Actual Class Environment Profiles for Peter's and Sandra's Classes

Students' perceptions of the learning environment within each class are consistent with the observers' field records of the patterns of learning activities and engagement in each classroom. The high level of Personalization perceived in Sandra's classroom matches the large proportion of time she spent in small group activities during which she constantly moved about the classroom interacting with students. Further, when Sandra offered desists, they were often private and she was never heard to use sarcasm or personal criticism in her interactions with students. It is significant that, of the 27 students of Sandra's class intending to return to school the following year, 24 of them expressed the wish to have Sandra as their teacher. The lower level of Personalization perceived in Peter's class is associated partly with the larger amount of time spent in the whole-class mode and the generally public nature of Peter's interactions with students. He spent much less time than Sandra dealing with students in quiet, small group situations.

The second significant difference between the learning environments was the lower level of Order and Organization in Sandra's class compared to Peter's class. Sandra's class was found by the researchers to be noisier than Peter's and the high level of off-task behaviour (mainly social) are consistent with the students' perceptions of a less orderly class. The physical arrangement of the classroom also contributed to the different levels of off-task behaviour. To make it easy for them to work together in groups, Sandra's students sat around tables formed by two desks. Unfortunately, this method of seating not only encouraged social interaction but also hindered effective scanning of the class for management purposes. As a result, many students, with their backs to Sandra, were able to carry on with their social agenda even during her whole-class presentations. In contrast, Peter's classroom had the desks in rows facing the front of the room where Peter spent about half of the lesson time using the whole-class instructional mode. This seating arrangement facilitated management scanning and Peter quickly targetted potential noise-makers for effective public desits. As a result, Peter's class was more effectively managed than Sandra's in terms of the proportion of student-engaged time.

Nevertheless, because Sandra endeavoured to keep the class on task with her quick movement around the class, helping students with problems and encouraging them to keep working, the perceived Task Orientation was moderately high, even on the second topic, when students spent more time off-task.

The difference in the classroom environments created by the two teachers also can be considered in terms of the metaphors adopted. For Personalization for Peter, for example, some students were confused by the way that they were treated in a depersonalized way as crew during whole-class activities (Captain role), but treated in a very friendly way during individual activities (Entertainer role). Moreover, only some students liked their personal interactions with Peter during individualized activities because it was not uncommon for Peter to interact with boys in a "macho" way and with girls in a sexist way. Consequently, it is not surprising that Peter's class on average perceived a relatively low level of Personalization. Similarly, the very high level of Personalization perceived in Sandra's class is also consistent with her metaphor of the teacher as Resource. Her teaching approach almost exclusively involved individualized work (about 75%) and she devoted great amounts of energy to moving around the class to give students individual help.

The low Order and Organization perceived in Sandra's class is linked with her commitment not to use whole-class teaching. Although she appreciated that Order and Organization would be likely to improve in whole-class situations, her strong beliefs led her to concentrate on individualized approaches. In particular, Sandra's time was monopolized by a group of girls who were eager to learn and by a group of disruptive boys who Sandra tried to control through proximity desists. Of course, with so much of her time devoted to these two groups, there was a natural tendency for the other students in the class to be off-task and for the average class level of perceived Order and Organization to be low. On the other hand, Peter's management metaphor, especially his role as Captain of the Ship, resulted in levels of perceived Order and and Organization that were higher than in Sandra's class.

CONCLUSION

The combination of the quantitative classroom environment data with the qualitative observational data led to complementary views of life in the two classrooms studies in this research. The field observations of classroom activities and student engagement build the same kind of picture that students' reported in their perceptions of their learning environment. For example, Sandra's emphasis on group work, the physical arrangement of the classroom and her personal management techniques resulted in a classroom which students' perceived as personalized but disorderly. It is doubtful that further improvements in the order and organization of her classroom could occur unless Sandra changed the seating arrangement to deter social interaction among the students. Because of her belief that students learn best by working by themselves and because of her role as Resource, Sandra was reluctant to make this change to her classroom. In contract, Peter used more whole-class teaching strategies, and his well organized but teacher-centred classroom was perceived by students to be orderly but less personalized.

The manner in which each teacher implemented the curriculum made it difficult for students to engage in a manner which was conducive to high-level cognitive learning. Sandra circulated the class attending to student requests for assistance, but despite her efforts to keep them on task, students were easily distracted from concentrating on their work. Peter managed the class in a more teacher-centred manner and focused on the learning of facts and completion of the work prescribed in the workbooks. Students were kept on taks, but Peter's frequest explanations of work and checking of answers made it easier for students to complete tasks witout having to think very much for themselves.

When this study commenced, we held the view that major problems in science teaching were associated with the predominant use of whole-class activities. In this study a better balance between small group and individualized instruction was no guarantee of success. The findings of the study emphasize the importance of teachers' beliefs about what ought to be taught and how students learn. The metaphors and images which teachers use to conceptualize teaching and learning appear to have a strong effect on how the curriculum is implemented.

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SCHOOL EXPERIENCE IN PRESERVICE EDUCATION: EXAMINING SOME ASSUMPTIONS

Jeff Northfield

INTRODUCTION

The teaching practice component has an undeniable place in any preservice education program. In Australia, teacher registration requires at least 45 days of supervised teaching practice. This very essential nature of the requirement may explain why it is taken for granted. It is often disconnected from the remaining preservice requirements and in many ways an unresearched area of preservice education. There is growing recognition of the need to attend to the way student teachers learn in the school setting in a way that identifies the ecological characteristics of the teaching experience (Zeichner, 1986a).

> "...relatively few researchers have actually examined what takes place during the experience itself and how professional life is interpreted and acted upon as students participate in its ongoing affairs." (Tabachnick and Zeichner, 1984, p. 29)

This particular preservice program has been developed during the last 10 years to prepare science teachers (Northfield and Gunstone, 1984). This paper examines a further revision of the approach to develop a stronger connection between course work and the practical teaching experience. This led to a restructuring of the teaching experience component of the course for one group of students. The monitoring of this revision provided an opportunity to study this group of students in the host school environment.

Developing a school experience which forms a coherent part of the total program

The review of the school experience took place in a context of some widely held reservations about the effectiveness of the existing practice. There was also a desire to develop a practical experience which was more consistent with a set of principles and procedures that had been developed and implemented for the campus components over a period of ten years.

The positive value of the practical experience is clearly appreciated by the participants in preservice education. However, weaknesses in the way the practical experience functions are recognized (e.g. Zeichner, 1986b, p. 16). There are widespread concerns related to a lack of an explicit curriculum for the practical experience, wide variation in the quality of school supervision and lack of status and commitment for supervision on the part of tertiary staff. In addition the three week teaching round blocks are associated with some more specific concerns about the practical experience. There is insufficient time to get to know the school and its staff and students. The short time means that the priorities are inevitably related to classroom activities and other aspects of the teaching role and neglected. It is impossible to gain experience in a full range of teaching experiences (e.g. planning, teaching and assessing a unit of work) and therefore difficult to apply many ideas from the campus coursework. This recognition that there was room for improvement in the practicum was considered in light of a series of principles which had been developed by a group of staff to provide guidelines for reforming the teacher education program.

Over a period of ten years the preservice program at Monash University has been developed according to a set of principles (Gunstone and Northfield 1987, 1988). These principles will be set out as a series of propositions with possible implications for course design particularly in the organisation of the practicum.

Proposition 1: The prospective teacher has needs which must be considered in planning and implementing the program. The nature and intensity of these needs will shift during the preservice program.

This proposition was clearly expressed from the outset and formed an important argument for revising the original program. Initial research had been undertaken with student teachers (Fuller, 1969) and further developed into a more general approach to thinking about change and teacher development (Hall and Hord, 1987). Initial needs/concerns of student teachers are largely personal (e.g., Will I be able to cope in the classroom? Have I made the right decision to try teaching?) There is strong evidence that these concerns have to be addressed and to some extent satisfied before student teachers will address other concerns (management of teaching and impact on students of teaching and learning approaches.

In the program within the faculty, consideration of this proposition has lead to a course which changed in emphasis throughout the year. The first 5-7 weeks includes a large number of activities directed to personal concerns (e.g. initial teaching experiences in less threatening situations to increase chances of success). Time was found by limiting the foundation subjects in the first part of the course and concentrating on a "personal preparation for teaching" theme.

When considering how this proposition might influence the practicum it became clear that the practical experience should also follow an initial experience of this kind and the school should be familiar with and as far as possible contribute to the first confidence building experiences for the student teachers.

Proposition 2: The transition from learner to teacher is a fundamental perspective and difficult to achieve. It is greatly facilitated by having intending teachers work closely with their colleagues.

Implied in this proposition is the value position that student teachers learn from each other. Yet teaching can be such an isolating activity as individuals work in their own classrooms. The moves to school based autonomy in curriculum matters seems to require a preservice program (and particularly a practicum component) which emphasizes teachers working collaboratively. The criticisms that school autonomy seems to be implemented as teacher autonomy may be an outcome of this failure to see some aspects of the teaching role as requiring trust and confidence in working with colleagues.

An important part of this emphasis on building confidence was the organisation of student teachers into groups of 15-18 for the majority of their course. This created opportunities for peer support and commitment to learning from each other. When the group of student teachers in this study began their practicum they did not enter the school as an individual but in the company of colleagues who had contributed to their development in the first weeks and were likely to be useful resources during the practical experience. It was also hoped that the supervising teachers might be seen as colleagues and genuine collaboration would occur in areas of materials development and team teaching.

This proposition in further supported from ideas of professionalism which emphasize the importance of reflection of practice (Schon, 1983). Various action research accounts (e.g. Baird and Mitchell, 1986) highlight the importance of colleagues in the process of reflection on practice. A willingness to share experiences and provide support for colleagues is crucial in teaching and it was hoped that the preservice practicum would provide an experience which developed attitudes and skills to work with others in reflecting on practice.

The transition from learner to teacher can be thought of as a shift from a dependent learner to a person who understands and controls their own learning (and the learning of others). In developing this understanding of the teaching/learning process the new teacher must benefit from the opportunity to discuss common experiences with colleagues. The practicum is a place where powerful early experiences will occur and the opportunity to discuss reactions and ideas with colleagues seems to be a very important part of the transition to a teacher.

Proposition 3: The student teacher is a learner who is actively constructing views of teaching and learning based on personal experience and strongly shaped by perceptions held before entering the program.

This view that teachers construct their own meaning about teaching and learning from experiences has been important in reshaping the preservice program (Northfield and Gunstone, 1983). In the campus course work, responding to this proposition has resulted in significant changes with an emphasis on providing experiences which challenge existing conceptions of teaching and learning, the academic disciplines which teachers will teach and even personal understanding of self. On campus it was possible to develop experience, workshops and mini-courses to encourage student teachers to reconsider existing views. Discussions with school principals and staff indicated that the practice was not challenging student teacher perceptions of the teaching role and a strong view was expressed that the three week block teaching experience was not a valid experience. In describing the experience as "a classroom experience but not a school experience" one principal highlighted the fact that most student teachers had no conception of the complex and variable role of a teacher and the practicum was providing little opportunity to broaden their understanding. The challenge was to develop a "practicum curriculum" which allowed student teachers the opportunity to experience a teaching role which includes curriculum committees, school councils, subject meetings, remedial and gifted programs, field excursions, writing reports, parent teacher meetings etc. It became clear that the school needed to play a more significant part in providing a practical experience that would open up the school and its full range of activities beyond the provision of classroom experience.

Proposition 4: The program should model the teaching/learning approaches being advocated.

The faculty staff associated with the program have always been willing to review and reflect on their practices. This often meant taking risks with status and relationships to make learning about teaching a more active process. By extending this proposition into the school experience we were asking the school and its teachers to risk sharing all aspects of their professional life. All teachers in the school needed to accept student teachers if a more valid school experience was to be achieved.

Proposition 5: Student teachers should see the preservice program as a worthwhile educational experience but by definition it is only the first stage in a career which requires continual professional development.

This proposition would be fundamental to any preservice program but it is clear that the practicum has the potential to provide a particularly significant experience. It was important to make the practicum a worthwhile educational experience by allowing student teachers to make decisions from among the range of experiences available in the school. It seemed possible to have the student teacher accepted as a person who makes a significant contribution to the school during the practicum. If the student teacher-supervising teacher relationship could develop into a collegial relationship then the supervising teacher may gain professionally. New curriculum materials and teaching strategies may be used and discussed and the student teacher may see the supervising teacher as someone who continually reviews the teaching process.

These propositions had formed guiding principles for a preservice course which differed in important ways from the mainstream course in the faculty. The way in which these propositions were applied to develop a curriculum for the practicum is outlined in the next section.

Reviewing the practicum: Applying the propositions. In 1987 a school's interest in reviewing its contribution to teaching practice provided a stimulus for introducing an alternative approach to the practicum. The "curriculum" for the practicum was negotiated between the school and the author and its essential characteristics were as follows:

- The practicum was a ten week school experience for 14 student-teachers in term 2 of the school year. The student-teachers had completed five weeks of activities as a group (see proposition 2 above) and a three week teaching round. They were to spend each school day in the school with seminars to be organised at the school by the author as required. Some of the student-teachers were required to drive the short distance to the university to attend some method sessions.
- Although each student teacher was allocated to two supervising teachers for practical teaching in the method areas, a staff meeting had approved the plan and accepted the practicum as a total school responsibility.
- Students were expected to observe and teach at least the same number of classes as would be required on a three week teaching round. In addition student teachers were invited to participate in all aspects of the school (school council meetings, integration of the disabled, sporting teams, staff meetings at all levels, field excursions, remedial programs etc.)
- The author agreed to "live" in the school for the term to arrange seminars involving student teachers and school and university staff. There was also a desire to maintain contact with the group of student teachers as they progressed during their preservice

year. This included supervision of practical teaching and informal discussions with both student teachers and school staff. The continued presence in the school setting as a member of the school-based group provided an excellent opportunity for the author to study what happened to student teachers during this school experience.

The student teacher and the practicum: establishing some directions

The practicum is widely regarded as the place where student-teachers apply educational ideas from their course work. The value of lesson planning which caters for pupil abilities and interests is assumed and practice teaching provides the opportunity to develop the skills and experience to achieve this goal. As an observer and participant in student discussions about lesson plans it was interesting to note that pupil abilities and interests did not emerge in planning decisions before weeks four and five. In the early weeks, lesson planning was limited to the best ways of organising and presenting content. For the student-teachers, lesson planning changed from a routine required for supervisors to a purposeful activity closely related to abilities and interests of known pupils. The difference in the nature of lesson planning discussions between early and later weeks was quite marked. Teacher education staff who expect that student teachers will gain any understanding of their pupils (and modify their behaviour accordingly) in less than five weeks are probably being unrealistic.

Schools are willing and capable of contributing to a practical experience which extends beyond classroom teaching opportunities. The possibility of a curriculum for the practicum will require schools accepting a greater responsibility for teacher preparation. The school is a very rich and appropriate environment to help people learn about teaching and the first hand experiences that can be provided are necessary for student teachers to appreciate the complex role of the teacher.

There was an expectation that the school-based program would prove valuable for student teachers. There was a hope that the school would benefit from the presence of student teachers. There is ample evidence that this hope was realized. Among the comments provided by the supervising teachers at the end of the extended experience were the following:

> "Because there was more time I had a greater commitment to working towards real improvement in her (the student teacher) teaching"
> "I learnt heaps from her (the student teacher). She revived my interest in ideas I had shelved for some time."
> "I could see my trainee develop confidence and she had time to reflect on the whole school rather than her two small teaching areas".
> "I have taught for many years and I have not experienced all the aspects of this school's life in the way the trainees have. I envy them that opportunity..."
> "It (the school experience) was of benefit to the school because, rather than disrupting our program for a short three weeks, it has enhanced our program for a full term."

> "Due to the student teachers' enthusiasm and active participation in many aspects of the school's curriculum, they have proved to be a positive resource for the school."

Supervising teachers found that they had to form a different relationship with a student teacher for ten weeks when compared to a three week period. It was a relationship which included team teaching, materials development and a sharing of ideas. Some school staff observed and incorporated assessment and teaching techniques making the practicum an inservice experience for the school. The student teachers were encouraged to explore all aspects of the functioning school, providing experiences which contributed to the foundation studies in the later stages of their Dip. Ed. program.

CONCLUSION

The practicum curriculum has been identified as a key area for development (Price 1987). There is a need to bridge a perceived gap between the course work in the tertiary institution and the practicum in the school. Turney et. al. (1985) describes two aspects of this gap as:

> "... the gap between the theoretical knowledge propounded in teacher education programmes and the experience of students in the practicum, and the real world of work undertaken by teachers in today's school" (p.xii)

This paper outlined one attempt to address this gap and provide a link between university and school. The approach had the following features:

- It was based on a set of propositions which had formed the basis for reform of the preservice course program. These propositions were extended to a revised practicum for one group of student teachers in one school. (In 1988 the approach has been extended to two further schools).
- A more extended experience (in both time and scope) was arranged to allow for a more meaningful application of course ideas (e.g., lesson planning and individualised learning ideas) and more valid experience for analysis in subsequent course work.
- The school staff became key agents in developing a school experience and so accepted a shared responsibility for teacher preparation. There was certainly a commitment to a successful school experience when the staff had such an important role in shaping the program.
- Teaching was presented as a collaborative activity with student teachers entering the school as group expecting to support each other. The supervising teachers formed a collegial relationship with the student teachers resulting in mutual benefits for the participants.

Developments in the practicum will depend on negotiating school (rather than teaching) experiences with schools. This paper indicates that there are schools who accept an increased responsibility and can provide an experience which benefits both the school and student teachers.

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ADULT SCIENTIFIC AND TECHNOLOGICAL LITERACY: A REVIEW

R.A. Schibeci

INTRODUCTION

"Science education in crisis" is currently a popular catchcry. Western politicians urge industry to be more technologically efficient. The pace of change, includng technological change, is increasing. "Citizens need to be scientifically and technologically literate", we are told (see, for example, the special issues of the Bulletin of Science, Technology and Society (1986, 6 [2 & 3] and 1987, 7 [1 & 2]).

What is "scientific and technological literacy"? Are they two concepts or one? How do people in the community become more "literate" in science and technology? What is the role of the school and non-school agencies (such as the media) in raising the scientific and technological literacy level of the community?

It is useful for this discussion, first, to provide a framework for the various sources of learning in science and technology. These sources may be categorised as "school" or "out-of-school". In each of these two categories, the provision of learning may be "formal" or "informal". Formal sources of learning are those which set out intentionally to educate; informal sources are those which educate "accidentally" (Lucas, 1982). Thus, the school provides "formal" learning opportunities in a science class, and "informal" opportunities in a science club. The "formal" classroom provision of science learning tends to be tightly structured, with the specific intent (generally) of achieving pre-determined objectives. The "informal" source of learning (the science club) is generally much less structured and often has a much greater emphasis on enjoyment as an important objective. In a similar way, an "out-of-school" source of learning may be "formal", as in a museum (in which there is a deliberate attempt to educate), or "informal", as in a play, a novel, a film or a television programme. The framework for the various categories of sources of learning are summarised in Table 1.

TABLE 1

A Classification of Sources of Learning
With Examples

	FORMAL	INFORMAL
School	science class	science club
Out-of-School	museum	novel/play

Let's now consider some of the meanings given to 'scientific and technological literacy'.

Scientific and technological literacy: What are they?

The concept of "scientific literacy" has been around quite a while, so let us examine it first. It has been defined in many different ways: a sample of views is as follows.

> gaining scientific literacy is a matter not merely of evolving from primitive ideas to complex ones, but of tearing out and replacing a whole, originally functional world picture, with all its concepts, hypotheses and metaphors.
>
> (Holton, 1984, p. 6)

> These two dimension together - an understanding of the norms of science and knowledge of major scientific constructs - constitute the traditional meaning of scientific literacy as applied to broader populations. But if scientific literacy is to become truly relevant to our contemporary situation, one additional dimension must be added: awareness of the impact of science and technology on society and the policy choices that must inevitably emerge.
>
> (Miller, 1983, p. 31)

> We may define science literacy as an acquaintance with science, technology, and medicine, popularized to various degrees, on the part of the general public and special sectors of the public through information in the mass media and education in and out of schools.
>
> (Shen, 1975, pp. 45-46)

Clearly, a wide range of elements is included in the concept of various authors. How are we to make sense of this bewildering range of views of "scientific literacy"? Some, like Maarschalk (1986), have abandoned the attempt, and instead have chosen to focus on selected apsects of scientific literacy. We must bear in mind, however, the consequences of illiteracy; in the words of the Australian Minister for Science,

> those who have no understanding of the ideas and practices of science...are as effectively cut off from the wider culture as those who have not yet learned to read or write. (Jones, 1986, p. 20)

Literacy in the natural sciences and technology are obviously important areas of concern.

This concern is not new. Pella, O'Hearn and Gale (1966) attempted twenty years ago to unpack the concept of scientific literacy. They began by identifying what they saw as three basic reasons for teaching science from kindergarten to university: "to prepare scientists"; "to prepare technologists"; and, "to provide a background in science as a part of the general education of the individual for effective citizenship" (p. 199). Achievement of this third purpose of science education, they believed, would result in a "scientifically literate" person. They systematically reviewed the science and science education literature (for the period 1946-1964) for "referents" to scientific literacy. Analysis of 100 documents led them to identify six such referents: science and society; ethics of science; nature of science; conceptual knowledge; science and technology; and, science and humanities. They summarised their findings in this way:

> The scientifically literate individual presently is characterised as one with an understanding of the (a) basic concepts in science, (b) nature of science, (c) ethics that control the scientist in his work, (d) interrelationships of science and society, (e) interrelationships of science and the humanities, and, (f) differences between science and technology. (p. 206)

Further, they claimed that the literature indicated that the first three were "more important" than the remaining three referents. Those with all these qualities would be more than "scientifically literate"; they would be Renaissance persons, par excellence!

A somewhat different view is provided by Shen (1975). He divided scientific literacy into three categories: practical, civic and cultural. He defined practical science literacy as "the possession of the kind of scientific knowledge that can be used to help solve practical problems" (p. 46). Such knowledge, he claimed, can mean the difference between health and disease or life and death for many people. In his view, the delivery of practical science literacy would require a large mass communication effort linked perhaps, with "alphabetic literacy (reading and writing)", although the latter is not a prerequisite for the former. In fact, there may be a case in some instances for giving a higher priority to increasing practical science literacy than to increasing alphabetic literacy. (For example, in some areas of health or nutrition, a basic knowledg is essential for a healthy life).

Shen's second category is civic science literacy, the purpose of which is "to enable the citizen to become more aware of science and science-related issues so that he and his representatives would not shy away from bringing their commonsense to bear upon such issues" (p. 48). Thus, while the experts would decide how a project would be implemented, citizens would decide whether the project would go ahead. He urged the raising of the functional level of civic science literacy by two means: first, by increasing the quality of quantity and science in the media, and ensuring that school science provides a solid foundation for future citizens; and, secondly, by an analysis ("in plain English"!) of current issues which have a science and/or technology dimension.

The third category Shen labelled cultural science literacy, which "is motivated by a desire to know something about science as a major human achivement" (p. 49). In Holton's (1984) words, the person with cultural science literacy has moved from a "somewhat pre-Aristotelian picture of the natural world" to a "post-Darwinian, post-Einsteinian" view.

Shen's view of practical, civic and cultural scientific literacy provides a useful starting point. Raising the level of scientific literacy is an important aim for a community, if only to improve the health of its people. That is, we need (as a first step) to raise the level of practical science literacy; beyond this, we can try to raise the level of civic science literacy and (most difficult of all) cultural science literacy.

What about "technological literacy"? Is it synonymous with "scientific literacy"? This requires us to examine the two concepts, "science" and "technology".

In a background paper to a SITCO (1986) report in Western Australia "science" was defined as "the process and the publicly accessible product of our attempts to describe, explain and predict natural phenomena" (p. A8) while technology is "the systematic process, and the product, of designing, developing maintaining and producing artefacts". The author of this background paper argued strongly that technology was not merely "applied science". Indeed, much of what is commonly regarded as the "history of science" is in fact "history of technology", he argued.

Perhaps we can draw a parallel with Shen's categories of scientific literacy and develop the categories of practical, civic and cultural technological literacy. Practical technological literacy would be the possession of technological knowledge which we need to solve practical problems. Civic technological literacy would enable citizens to be aware of technology and technology-related issues so that they can help decision-makers to make rational, informed decisions. Cultural technological literacy would be characterised by a desire to know something of technology as a major human achivement.

Scientific and technological literacy: Who provides for them?

Lucas (1983) argued that scientific literacy could develop from a variety of sources, both "school" and "out-of-school". That is, while it is reasonable for a community to look to its schools as a mechanism for improving the level of scientific and technological literacy of the young, there are also many sources of out-of-school learning (Table 1 identified the various categories of sources of learning).

Unfortunately, there is much evidence which shows that school science generally presents a view of science which is distorted and vague. Gordon (1984) characterised this view as a "bucket image" of science, which does not correspond with actual science practice. Some of the elements of this "bucket image" are:

> Scientific truth exists "out there". It consists of a collection of facts. We today know some of them. At one time, fewer were known and in the future, more will be known. Scientific knowledge accumulates steadily. Generally there are no revolutions in science. It rarely occurs that a statement believed to be true is discovered afterwards to be untrue... With regard to facts as yet unknown to us, the reason they are unknown is that scientists haven't gotten around to discovering them. When they have the time, they will discover them, because discovering these facts isn't problematic, at least not for scientists, who are clever people. (p. 372)

If Gordon's analysis is correct, then much work remains to be done to improve scientific literacy among school age children. Technological literacy also needs to be improved. In Australia, the attempt to introduce a "technology studies" for all students is a recent phenomenon. In Western Australia, for example, a 'Technology Studies' unit (a 40 hour unit) has recently been trialled. It emphasises the difference between science and technology, and stresses the accessibility of much technology to all, not just to a group of specialists.

For those who have left school, we must turn to other sources, some formal, and some informal. Of these, television is potentially the most powerful. In an interesting article "Marcus Welby, MD' as Medical Communication", O'Connell (1975) discussed the impact of this show on viewers. He began by pointing out the enormous impact of television as

> an awesome tool of communication...this places a tremendous responsibility on the producers of...medical programmes to be authentic medically, while supplying stories dramatic or entertaining enough to attract a continuing audience (p. 165).

He emphasised the value of such a programme as "a public service". A documentary on any of the issues which have formed the basis of 'Welby' stories (abortion, enthanasia, teenage pregnancy, sexual assault, to name but a few) would, he pointed out, attract limited audiences. 'Welby', on the other hand, reached a weekly audience of 40 million in North America. Thus, it provided a very powerful medium for medical science education outside the school. Part of its attraction, of course, is that it deals with medicine, which interests all of us. (In a recent analysis of science on television in Australia [Schibeci et. al., 1986], we noted that medical stories constitute by far the largest group of stories in each show, presumably because of the public's interest in matters medical). As O'Connell pointed out, a "medical show such as Marcus Welby, MD is inherently instructional as well as dramatic entertainment" (p. 170).

Schools must continue to work hard to produce scientifically and technologically literate graduates. Both school and out-of-school sources of learning have the potential to raise the level of scientific and technological literacy of our community. Educators must try harder to make both sources of learning work.

Adult scientific and technological literacy

How can we raise the level of adult scientific and technological literacy? One approach is to identify a variety of adult needs. We can try to show adults that science and technology are of direct relevance to everyday life. In the longer term, hopefully, these adults will be able to participate more effectively than they currently do in decision-making processes on issues involving science and technology.

One research strategy that is relevant here has a focus which has been labeled "science-for-specific-social-purposes (SSSP)" as outlined by Layton et. al. (1986). That is, the focus here is on specific aspects of science and technology which impinge on adults' out-of-work activities, as a way of narrowing the gap between adults and science and technology. This approach can be contrasted with the "general survey of knowledge and perceptions of science and technology" approach which has been used, particularly overseas (for example by Miller, 1983).

Research in adult scientific and technological literacy is clearly needed because, as a review by Eckersley (1987) has shown, no systematic work in this area in Australia has been done.

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ERNST MACH AND THOUGHT EXPERIMENTS IN SCIENCE EDUCATION

Michael R. Matthews

INTRODUCTION

Ernst Mach (1838-1916) was one of the great philosopher-scientists of the pre-modern period. He was a truly Renaissance Man: a master of most European languages; a reader of the Greek and Roman classics; a physicist whose contribution to diverse fields such as electricity, gas dynamics, thermo-dynamics, shock waves, optics, energy conservation and mechanics, were outstanding; a historian and philosopher of science; a psychologist; the Rector of Prague German University; a member of the Austrian parliament; and the writer of wonderful, lucid prose.[1] By all accounts his character was as pleasant as his intellectual achievements were grand. William James, who met Mach in 1882, wrote to his wife that

> I don't think anyone ever gave me so strong an impression of pure intellectual genius. He apparently has read everything and thought about everything, and has an absolute simplicity of manner....that (is) charming (Feberabend 1981, p. 64).

He was a socialist, and a liberal-humanist in the very centre of the arch conservative, and Catholic, Austro-Hungarian Empire.

Mach's first publication was in 1859, the year of Darwin's The Origin of Species; his last was published posthumously in 1921, the year of Einstein's Relativity: the Special and General Theory. He contributed to the accomplishments of Boltzmann, Maxwell, Planck, Poincare, Einstein, and indeed most of the physicists who were preparing the ground for the revolution of modern physics. This contribution is echoed in such common-place terms as Mach principle, Mach bands, Mach angle and Mach number. Einstein often acknowledged the debt he owed to Mach for the formulation of his relativity theories (Hoffmann 1977, p. 78, Holton 1970).

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1. Accounts of Mach's life and achievements can be found in his enteries in the Encyclopedia of Philosophy, and the Dictionary of Scientific Biography. Additional material can be found in Blackmore (1972), and Cohen & Seeger (1970).

Mach's contribution to philosophy was enormous. This was through his influence on the early members of the Vienna Circle - Rudolph Carnap, Phillip Frank, Moritz Schlick and Otto Neurath. Indeed this group initially met as the "Ernst Mach Society" (Ayer 1959). Whether this contribution was helpful or harmful has been the subject of fierce partisan debate. Mach's philosophy has been attacked both from the Left and the Right. Lenin's Materialism and Empirico-Criticism was directed squarely against what he saw as Mach's Berkelian-like idealist tendencies. J.D. Bernal popularised these criticisms in the West (Bernal 1959). On the other side Karl Popper has been a long-standing critic of Mach's instrumentalism and phenomenalism (Popper 1959, p. 59). Elie Zahar is one of the many Popperians to repeat these charges (Zahar, 1977). Paul Feyerabend has made a concerted effort to rescue Mach's philosophy from the attacks of these critical rationalists (Feyerabend 1981, Vol. 2). This effort has been somewhat in vain: Mach's reputation among philosophers is not high. When the empiricist tide ebbed, it took with it Mach's philosophical reputation. This was unfortunate as he was much more sophisticated than many of his critics have recognised.

I do not wish here to rehearse these philosophical arguments. I wish to draw attention to Mach's long-overlooked contribution to educational debate, and particularly to his proposals for science education. These are strikingly modern and of great relevance to constructivist-inspired debates in science education.

Mach is noteworthy in his period for being a major scientist who concerned himself with educational matters: most did not. The only comparable scientist is Alfred North Whitehead, whose Aims of Education appeared in 1929. Mach was the son of a school teacher. He was early on influenced by the ideas of the German philosopher-psychologist-educationalist Johann Friedrich Herbart (who had succeeded to Kant's chair at Konigsberg, and who almost followed Hegel at Berlin). In 1887, with G.B. Schwalbe, Mach founded a journal devoted to issues in physics and chemistry instruction (Zeitschrift fur den physikalischen und chemischen Unterricht). He edited and contributed to this journal through to his retirement in 1900. Whilst at Prague German University from 1867 to 1895 he taught courses on high school physics teaching. He lectured extensively to school teacher associations. He wrote many physics textbooks; books that were used at school and university by nearly all the great European scientists of the latter half of the nineteenth century.

Mach's efforts on behalf of science education were of course conducted at a time when the very teaching of science in high schools was a matter of dispute. In England, Thomas Huxley had been arguing with Matthew Arnold for the recognition of science in a liberal education. In Germany the classical Gymnasium excluded the teaching of science and mathematics.

Elite education was regarded as a classical and literary education. The president of the Berlin Academy had just a century earlier (1752) proposed establishing a city in which only Latin would be allowd to be spoken, this to train and discipline the minds of children. Science was taught in designated schools - Realgymnasiums, and there it was taught in a most Prussian manner (Arnold 1868). Mach's own university teacher, Ettinghausen, in the 1850's became the first professor in a German university to introduce student laboratory exercises as a supplement to lecture-demonstrations in science. It was this fact-laden, cook-book style of science education that Henry E. Armstrong was at the time arguing against in England (Armstrong 1903).

Mach's theory of science, his view of what science is, in large measure determined his approach to science pedagogy. This approach has a number of central themes that are surprisingly modern, the more surprising given the avowed empiricist commitments of Mach. These themes include the following:

1. Science is fallible, it does not provide absolute truths.
2. Science is an historically conditioned intellectual activity.
3. Science ought to be unified, the compartmentalization of the disciplines is artificial.
4. Scientific literacy is an integral part of any education.
5. Scientific theory is best understood if its historical development is understood.
6. Individual scientific learning is enhanced if it proceeds historically.

One can see in this constellation, elements of Thomas Kuhn, Jean Piaget, Gerald Holton and the constructivist school of science education. The rock-bottom claims are that all human cognition is radically historical, and that its adequacy is to be tested ultimately in some form of experience.

For Mach all intellectual puzzles - be they about why people like to be ruled by a king, why there are wealthy and poor classes, or why we believe in the conservation of energy - are to be resolved by the help of history. In science especially, "there is only one way to enlightenment: historical studies" (Mach 1911, p. 16). Science teaching was to be both practical and historical. Without experience and its conceptualisation, there are no puzzles; without history, there are no satisfying solutions.

> Whoever knows only one view or one form of a view does not believe that another has ever stood in its place, or that another will ever succeed it; he neither doubts nor tests (Mach 1911, p. 17).

Mach clearly saw that without a mathematical and scientific education "a man remains a total stranger in the world in which he lives" (Mach 1943, p. 359). Beyond this understanding, such education developed the strengthening of reason, judgment and the promotion of imagination. These abilities were enhanced to the extent that the curriculum was limited. "I know nothing more terrible than the poor creatures who have learned too much" (Mach 1943, p. 367). Of these Mach said

> What they have acquired is a spider's web of thoughts too weak to furnish sure supports, but complicated enough to produce confusion (Mach 1943, p. 367).

A novel aspect of Mach's approach to science education was the stress that he placed on pupil's participation in thought experiments (Gedankenexperimente). He said of this that

> Experimenting in thought is important not only for the professional inquirer, but also for mental development as such (Mach 1976, p. 143).

Not only the pupil, but the "teacher gains immeasurably by this method". It enables the teacher to learn what grasp students have of basic concepts and their interrelations. This stress on pupil's thought experimentation is similar to Joseph Novak's contemporary advocacy of concept mapping as a way for teachers to understand the thought patterns of their students.

Each issue of the pedagogy journal that he co-established carried thought-experiment exercises for classroom use. Such problems as a beaker of water in equilibrium on a balance has a suspended mass lowered into it: what happens to the equilibrium? Or a stoppered bottle with a fly walking on its base is in equilibrium, what happens when the fly hovers?

It is noteworthy that Mach the empiricist and sensationalist - who has been attacked by Karl Popper for the "obscruranticism" of his instumentalism (Popper 1963, p. 100), and by William Shea for his "Teutonic rigour" that blinded him to non-empirical achievements of Galileo (Shea 1977, p. 82) - was among the first to recognise the centrality of thought experiments in the history of science. He detailed the role of thought experiments in the achievements of Galileo, Newton, Huygens, Carnot, Joule and others.

Some thought experiments exposed conceptual contradictions in a theory. Such was Galileo's famous demonstration that the Aristotelian "speed of fall depends on weight" axiom was contradictory. He asked his audience to imagine a heavy and a light body falling separately, then to join them and predict what will happen. There is a contradiction: the composite ought fall slower than the original heavy body because it is retarded by the light body, but it also ought to fall faster because it is heavier than the original body (Galileo 1954, p. 60).

Other thought experiments concerned circumstances that could not be realised. Such was Galileo's criticism of the Aristotelian categories of natural and violent motions whereby for heavy bodies their natural motion was caused by a tendency to move to the centre of the earth. He asked his audience to envisage a stone dropped in a well, and then the well progressively deepened until it went through the earth's center and to the other side. What happens now to a dropped stone: does it stop at the centre or pass beyond? Once more conceptual problems are highlighted by imaginative constructions.

As with practical experiments, the method of variation is characteristic of thought experiments. Here we extrapolate from behaviour in known domains to that in unknown ones. Such extrapolations may lead to paradoxical outcomes. Mach recognised the importance of abstraction in science. Of thought extrapolations, Mach said

> Physically such a process is often impossible to carry out, so that we may speak of it as an idealization or abstraction (Mach 1976, p. 140).

The beginning of thought experimentation is to have students guess the outcome of an experimental arrangement. How do we obtain a square double the area of a given one? How do we make a pendulum swing with twice its period? Mach himself in a lecture on the speed of light came close to performing Einstein's classic thought experiment whereby the common understanding of the simultaneity of events was shown to be paradoxical (Mach 1943, p. 48).

Interestingly, given this train of intellectual events, Mach had observed in the above lecture that

> new thoughts do not spring up suddenly. Thoughts need their time to ripen, grow, and develop in, like every natural product; for man, with his thoughts, is also a part of nature (Mach 1943, p. 63).

For Mach the promotion of intellectual creativity, imagination and judgment by thought experiments was also a way in which the then wide gulf between a humanities and a scientific education could be bridged.

> The planner, the builder of castles in the air, the novelist, the author of social and technological utopias is experimentating with thoughts (Mach 1976, p. 136).

So too was the mathematician.

> The change and motion of figures, continuous deformation, vanishing and infinite increase of partiuclar elements here too are the means that enliven enquiry, tell us about new properties and promote insight into their connections. It is to be assumed that the method of physical and thought experiment developed first in this simply accessible and fruitful field and spread from there to the natural sciences (Mach 1976, p. 145).

Mach knew that "thought experiment is in any case a necessary precondition for physical experiment (Mach 1965, p. 136). He saw clearly that the "close conjunction of thought with experience has built modern natural science (Mach 1976, p. 146). Science education was to foster these imaginative and intellectual abilities.

> I would be satisfied if every young student could come into living contact with and pursue to their ultimate logical consequences merely a few mathematical or scientific discoveries (Mach 1943, p. 368).

This would be done only after the subject matter is made familiar by pictures and experiment. Geometrical experience should precede Euclid. But with this background, the final stages of a school education ought consist of "an appropriate selection of readings from Galileo, Huygens, Newton etc. (Mach 1943, p. 368). Not to learn dates and experiments, but to absorb and understand something of their style; to understand their theory. Mach agrees that "enquiry cannot be taught".

> However, the examples of great enquirees are very suggestive, and practicing thought experiments after their model as briefly indicated above is bound to be beneficial (Mach 1976, p. 146).

The course of twentieth century physics confirms the importance of thought experiment: Maxwell's demon, Schrodinger's cat, Einstein's train, Heisenberg's gamma-ray microscope - all of these are the imaginative constructions, extrapolating from the known, that Mach championed. Despite this rich and important heritage, few people since Mach have paid attention to the role of thought experiment in science education. It is characteristic of the neglict of Mach, that a rare, and excellent, recent publication on thought experiments and science education does not make mention of him (Helm et. al. 1985).

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LINKING THE AIMS OF PRACTICAL WORK TO ASSESSMENT PROCEDURES IN TEACHING SITUATIONS

P.P. Lynch and P. Webb

INTRODUCTION

Some background considerations related to the assessment of practical work

Seminars held by Tasmanian H.S.C. chemistry teachers in December 1984 and November 1986 overwhelmingly supported the view that any new practical assessment scheme for chemistry should be teacher-based and continuous in nature. Opinions expressed at those meetings and based on many years of teaching experience, in some case, were far less sympathetic towards the prospect of a return to external practical examinations. These opinions and attitudes regarding assessment tend to reflect current Australian opinion in most science subject areas and although there are no data on teacher preferences, most States in Australia would appear to be moving in the same direction judged by the recommendations and guidelines issued by individual Education Departments. However, there are three criteria to be monitored before one can feel confident that any new assessment procedure is working satisfactorily, namely validity, reliability and usability.

In the case of practical work, be it in chemistry or any other subject area for that matter, the validity of the items to be tested needs to be established. This is far from an easy task since the item list should presumably have some underlying theoretical rationale; be related to theory in a way which does not set up a fact/theory dichotomy, and be universally comprehended in the same way, i.e. items listed should have near identical meanings for different teachers. What should emerge from attempts to establish new assessment criteria is a common 'meta' language which is essential for dialogue and the absence of which can result in a major stumbling block to progress in its own right.

Development and validation of Chemistry Practical Skills Inventory CPSI

Such a development task may be approached in two ways:

1. By analysis of the practical tasks in a curriculum and determining the practical skills that are being demonstrated, therein.

2. By deciding 'a priori' what practical skills are desirable in a particular course and then designing practical experiences to cover these skills.

The fact that a totally new syllabus was being introduced into H.S.C. chemistry in 1987, encouraged use of approach 2. The expectation was that the practical experience would be related to an evolving CPSI and that any finalization of either the experiments or CPSI should take place at the summative phase of the project.

The develpment of the first form of CPSI relied on an extensive literature search but the major references used as guidelines were those provided by Tamir, Nussinowitz and Friedler (1980), Senior Secondary Assessment Board of South Australia Discussion Document (1985) Lunetta, Hofstein and Giddings (1981), Lunetta and Novick (1982), Kempa and Ward (1975), Hellingham (1982), Lunetta and Tamir (1979), Lynch (1987) and Kempa (1986). Most of the sources are review articles and it can be seen that U.S., U.K., Israeli and Australian recommendations were drawn upon.

A simplified draft form of CPSI, based on the literature search was then group-validated by the eighteen Tasmanian schools and college groups involved. Fourteen school groups returned the questionnaire which involved modification of the first draft of CPSI. However, it is worth noting that teacher responses from all fourteen schools were unanimously positive about the general framework and teachers accepted that a range of practical skills (wider than just handling skills) should be measured.

In relation to the comments made in the introduction, 10/14 school responses alluded to methodological problems associated with transforming CPSI into a reliable and usable assessment.

The simplified version of CPSI that was used in this study and the corresponding skill assessment sheet SAS are provided in Tables 1 and 2. It will be appreciated that CPSI is not a fully developed inventory like that of the Israeli PTAI, at this stage; and this was a deliberate policy decision by the researchers. The Chemistry skill assessment sheet SAS is simply a summary table of the skill categories. However, the decision was made by the chemistry teachers involved to weight the categories as follows: Planning design (10%); Manipulative skills (30%); Written Report (30%); Interpretation (20%). No magic formula was involved, this was simply a group decision taking into account course expectations and perception of level of development of the students. The categories covered will be discussed subsequently and should be seen in relation to the parallel study which involved a final examination (Lynch and Shadbolt ibid).

TABLE 1
CHEMISTRY PRACTICAL SKILL INVENTORY (CPSI)

1. Planning and Design
   - ability to conduct a practical exercise, i.e. to plan an experimental procedure and satisfactorily perform the operations in the correct sequence. May require modification of the original plan in the light of difficulties.
2. Performance
   - carry out qualitative observations
   - carry out quantitative observations
   - manipulate a suitable range of appratus (e.g. balance)
   - carry out specified operations (e.g. filtration)

3. Written Work
   - record results, describe observations
   - tabulate and graph
   - organisation and clarity of work

4. Analysis, Interpretation, Application
   - determination of qualitative or quantitative relationship
   - explain relationships
   - determination of accuracy of data
   - ability to constructively criticise experimental design
   - discuss limitations and assumptions of data
   - ability to generalise from experimental data
   - application of experimental technique to new situations

5. Attitude
   - appreciation of safety and other regulations in the laboratory
   - persistence and resourcefulness
   - enthusiasm - such as suggestions for work outside guidelines, and positive, active role in group work.

METHODS

The sample

The pilot study was conducted at Launceston College, a large secondary college in the Tasmanian city of Launceston. The student sample consisted of 105 students in 5 separate classes who were entered for Chemistry III which is the usual chemistry prerequisite for University entrance. Three experienced chemistry teachers were involved with the trials. All teachers had attended the seminars mentioned and were at least partially familiar with the background literature and in particular the purpose and status of CPSI and SAS.

Procedure

Teachers allocated marks to students within the five broad categories listed on CPSI, and SAS. The level of mental processing required by the assessor was taken as being at the level of CPSI but the level of recording was under the five broad categories of SAS. Thus, this is an exercise in intermediate skill coding and not detailed skill coding, in line with the observations and findings of Buckley and Kempa (1971). This should be seen as an initial response to the requirement of usability.

TABLE 2: SKILL ASSESSMENT SHEET (SAS)

(One kept for each student)

NAME: ....

Experiment Assessed	Planning & Design	Manipulative Skills	Written Work	Interpretation
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
TOTAL				
Weighted Score	/10	/30	/30	/20

Attitude /10

Total /100

Reliability was ascertained by a retrospective analysis of student performance data and internal consistency tests. It should not be thought that this decision was taken lightly. We were very conscious that reliability could be lost in intermediate skill coding to an extent which could make the whole operation untenable. However, the evidence for consideration as to whether the reliability is acceptable is provided subsequently.

The testing took place over the year 1987 and the experiments used were mainly adaptations of those taken from the Academy Text on which the H.S.C. syllabus was based though the listed experiments did not fully cover all the skills, particularly in the area of "planning". Over the year, individual students were assessed in respect to planning (2 occasions), manipulative skills (6 occasions), written reports (20 occasions), interpretation (20 occasions). At this stage manipulative skills were assessed directly and the other categories were assessed from written accounts.

RESULTS

Teacher's opinions regarding the assessment procedures used

Only 3 teachers were involved in this particular study but opinions regarding assessment procedures were sent to all chemistry teachers involved in H.S.C. chemistry (n=30) and replies were obtained from 19 (63% response rate). Both groups of responses are shown in Table 3, and the latter group are distinguished by being in parenthesis.

It should be noted that although the practical component counted for a significant coursework percentage (25%) of the overall marks, Tasmanian teachers were not required to provide a common pattern for assessment. This explains the difference observed in the frequency counts but more interesting is the degree of dissatisfaction found generally with the present non-specified approach. This was not observed for the Launceston College group who were very positive about the general criteria for the continuous assessment scheme used, and whose main comments were concerned with recommendations for improvements. The Launceston group also thought that the extra time spent was well worth the effort.

Students' opinions regarding the assessment procedures

Student opinions regarding the continuous assessment programme are generally very positive (see Table 4). The majority of new students (non repeaters) consider the amount of assessment, time allocation and feedback to be adequate and the instruments to be fair and accurate as far as they could judge. Most notable is the response of the repeaters. When asked to compare the assessment procedures used in 1986, which were largely holistic and intuitive, 100% of repeaters preferred the continuous assessment programme of 1987 and the response regarding feedback is particularly striking. The teachers involved in the study were both surprised and heartened by the student responses since they really did not know what to expect in this regard and were anxious about the possible intrusive nature of their procedures.

Table 3 Teachers' responses regarding assessment of the practical component in 1987: Launceston College/(others)

	Always Easy	Sometimes Easy	Never Easy
How easy to categorize the skills for the experiments?	0 (0)	3 (9)	0 (1)
How easy to assign marks within skill categories?	0 (0)	3 (8)	0 (2)
How easy to assess manipulative skills?	0 (0)	3 (0)	0 (5)

	More time	Less time
Spent more or less time on practical work than in previous year	3(14)	0(5)

	Yes	No
Was the extra time justified?	3(15)	0(4)
Were you happy with the form of assessment that you used?	3(9)	0(10)
Would you use your scheme again next year?	3(12)	0(7)

Student performance data

Student performance data consists of the marks allocated on all four categories on SAS, the "total practical mark", and the "total theory mark", for individual students.

This data was examined in relation to:

1. mark range and distribution;
2. cross correlation between items;
3. internal consistency checks;

and are reported, separately.

Mark range and distribution

As well as the frequency plots themselves, means, standard deviation and coefficients of variance were obtained as confirmatory measures. The findings can be summarised as follows:

"Planning" marks provide a bi-modal distribution, with the widest spread for all items listed (coefficients of variance 38.6).
"Manipulative" skills and the "Written Report" marks had very similar normal distributions over a relatively narrow mark range (coefficients of variance 14 and 15 respectively).
"Interpretation" mark and "Total Theory" mark had a very similar mark range with almost identical coefficients of variance (20.9 and 20.8 respectively).
The "Total theory" mark contained a small group of high performing students (n=9) who distorted the normality of that distribution.

Table 4 Students' responses regarding the assessment of the Launceston College practical component in 1987

		% Response		
	Student group	Too much	Correct amount	Not enough
Amount of practical assessment	repeaters	7	86	7
	non repeaters	11	76	13
		Adequate	Inadequate	No opinion
Time allocated for assessment	repeaters	67	32	0
	non repeaters	52	38	10
Feedback to indicate progress	repeaters	100	0	0
	non repeaters	76	16	8
Feedback to indicate standard	repeaters	57	14	29
	non repeaters	54	27	19
		accurate	inaccurate	no opinion
Perceived accuracy of instruments	repeaters	77	15	8
	non repeaters	65	23	12
		1986 preferred	1987 preferred	
Comparison with 1986 practical assessment	repeaters (only)	0	100	

Cross correlations

These are provided in Table 5.

The correlations of "total theory" with "total practical" marks is surprisingly good (0.78). However the continuous assessment at this stage is heavily oriented towards similar outcomes and is weighted towards paper and pencil responses. The correlation with manipulative skills is low (0.34) but not as low as reported in other studies. The lack of correlation between "planning" and "manipulative skills" (0.09) is of interest though there is a moderate correlation between planning and Total Practical Mark (0.49) and Internal Theory Mark (0.46).

Overall, the cross correlations are greater than reported in other studies and that includes the parallel study of a terminal-practical examination (Lynch and Shadbolt, ibid).

Cross Correlations between CPSI Items, Total Practical and Total Theory Marks

TABLE 5 Cross Correlations between CPS1 Items, Total Practical and Total Theory Marks

	Planning	Manipulative skills	Written Reports	Interpretation of data	Total Practical Mark	Total Theory Mark
Planning	X	0.09	0.43	0.43	0.49	0.46
Manipulative skills		X	0.37	0.48	0.50	0.34
Written Report			X	0.71	0.83	0.61
Interpretation of data				X	0.80	0.73
Total Prac. Mark					X	0.78
Internal Theory Mark						X

DISCUSSION

Implications for teaching

As with the parallel Tasmanian studies cited, this is an example of a curriculum research project which falls under the category of "teachers as researchers". In that sense its development depends on the growing, collective decision-making of the teachers themselves rather than imposition of a top-down policy decision. The latter approach seems to have largely failed, and failed very badly in first-world democratic countries. It goes beyond the bounds of this paper to explore the implications of this observation but it is perhaps worthwhile making the point that historically there is considerable evidence to support the idea that small committed groups can be surprisingly influential in the area of curriculum. Perhaps, Henry Armstrong and the X group may serve as an example from the early history of science education for the masses.

The action research component of this study involves a monitoring of student and teachers' perceptions, particularly in relation to appropriateness and usability (Tables 3 & 4). Whether the findings of the Launceston College group encourage others to make the same commitment to practical work and in an analogous way remains to be seen. The procedures were repeated in 1988, and again, it would appear that *usability* is not a major hurdle. At this stage there is no detailed inventory or intermediate skill coding list for chemistry that has wide acceptance. Acceptance of a more formal structuring and description of the assessment process is a major step but this has to be decided by the group.

The retrospective analysis of student performance data is illuminating. Correlation studies between assessment items tend to confirm the findings of the other Tasmanian studies. The lack of correlation may be taken as evidence for the *validity* of the item, i.e. different things are being measured.

At this stage, evidence for reliability is somewhat limited but the data are still being analysed. One general approach to dealing with reliability would seem worth reporting and that involves examining the *differences between variances* of marks for the different student groups. It would appear (based on F.tests) that there are no statistical differences for "total theory", "total practical", "written work" or "planning" but there are differences for "interpretation" and particularly for "manipulative skills". It seems unlikely that these differences are due to the students (who are randomly selected for their classes) but it does suggest that differences are due to the procedures for marking these items and/or the markers. Which really does point towards the need for a more formal inventory.

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THE CULTURAL ROOTS OF SCHOOL BIOLOGY IN AUSTRALIA - FROM VITALISM AND MECHANISM TO DIALECTIC MATERIALISM

Rod Fawns

INTRODUCTION

The revolt from morphology in Botany and Zoology produced a realignment of fields and traditions within the biological community in Universities in the early decades of this century. These changes have been traced by William Coleman (1978) and Garland Allen (1978) in the Cambridge History of Science Series. They show that by the time Biology was first being proposed seriously as a school subject in the twenties and thirties the criteria for satisfactory explanation within the life science were changing from the largely descriptive, naturalist science dominated by Darwinist influences to the laboratory oriented science of the fifties.

Biology was introduced as a school subject in the twenties in England, at first on account of those aiming to enter the medical profession, later because of the growing recognition of the need to recruit economic biologists and because of its perceived importance as a part of general education.

The early Australian school texts such as W.J. Dakin's Elements of Animal Biology (1918-35) and Gwynneth Buchanan's Elements of Animal Morphology (1921-43) followed T.H. Huxley's "type system" designed to make more concrete for students the study of bewildering diversity. However the authors of the first Biology texts such as Palmer's Living things - An Introduction to Biology and Hatfield's An Introduction to Biology (1938-60) noted that in the earlier texts the intended illustration of levels of evolutionary organization was often omitted while the problem of so many isolated life histories and facts of structure to be memorized remained. This they argued in the thirties could be solved by abandoning the type system in large degree, using man as the main animal type and making fundamental "activities" such as feeding, respiration, growth and reproduction the organizing ideas.

A clear distinction had long existed between medically related fields like physiology, biochemistry and microbiology and natural history fields dominated by gross morphology, but also taxonomy, biogeography, evolutionary embryology and comparative anatomy. The long standing separation between laboratory and field workers still surfaces occasionally but the introduction of experimental methods into all fields has brought about a fuller integration of biology as a field that did not previously exist. The synthetic process was difficult and drawn out and may help to explain the relatively late emergence of Biology as a school subject. The synthetic process itself provided the rationale for the sixties reforms in Biology teaching in America, England and elsewhere.

Aspirations to reduce all biological phenomena to physical laws were by the 1920s running counter to a new concern appearing first in both physics and physiology. That concern centred around satisfactorily explaining the organizational interrelationship between parts instead of treating parts in isolation. It involved new methods and approaches to the study of complex phenomena without destroying the organization.

E.S. Russell, the pioneer ethologist, wrote in 1933 of this explanatory method:

> ...the proper method for the biologist is to start with the activity of the organism as a whole and work down from this to the conditions of the whole-action. Both in animals and plants the first object of study should be environment-behaviour-responses in animals and growth-responses in plants. The biologist may properly analyse these whole-actions with the aim of discovering the physiological processes which underly them; he may profitably study these physiological processes in isolation in order to discern the physico-chemical events of which they are made up. But he should not start with the elementary processes and attempt to build up the living reality by adding these together, for the task is an impossible one, and will sooner or later drive him into accepting some from of dualistic vitalism. It is only by accepting the obvious fact that the living thing is an organised whole and not a mere summation of parts that the biologist can preserve the authonomy of his science and escape the Scylla of materialism on the one hand and the Charybdis of vitalism on the other.

The intellectual problem was that having discarded vitalism and mechanistic materialism because it failed to give any account of the co-ordinating or organising principle, a coherent conception of life had to be found. A new explanatory method was sought in the life sciences. This emerging holistic or dialectic materialism was found by the physiologist J.S. Haldane (1932) in the organism, the living functioning entity.

> The characteristic feature of life is that living organisms present a highly specific structure and set of activities, reproduced indefinitely often. In the light of detailed investigation, it is evident that all the phenomena in a living organism are dependent on its environment. But it is equally evident that the cause of this dependence is, in its turn, dependent on the organism itself.

Haldane argued that biological explanation was not concerned with causes in the same way as physical or clinical analysis, but was simply the demonstration by observation and experiment that an observed phenomenon comes under the general conception of life of an organism.

> Biological interpretation is essentially concerned with function. The whole life of an organism is expressed in the function of any particular part or activity, and just in proportion as we understand the whole life do we understand the function of any particular part of an activity.

Haldane admitted to being encouraged in his argument for the distinctive nature of biological explanation by the great synthesising vision offered by Max Planck and Neils Bohr. Quoting from Planck in the journal Nature that "the conception of wholeness must...be introduced into physics, as in biology, to make the orderliness of nature intelligible and capable of formulation," Haldane quipped that mathematical physics may henceforth be regarded as a backward branch of biology. The status of Biology as an experimental science was an important issue.

The discovery of viruses, living things of little more than molecular size, had appeared to many at this time to furnish a link in the extension of biological interpretation into what was regarded as the inorganic world of molecules and atoms. Joseph Schwab was amongst these. Trained as a geneticist, he taught a course on biological reasoning in a liberal arts programme in Chicago University through the forties to the sixties. Schwab clearly sought to extend the range of biological explanations into new areas in his students' thinking.

> ...The discovery of quantum phenomena strongly suggests the possibility of such an extension, which must be regarded as one of the scientific aims of biology. This is a very different aim from the essentially meaningless one of tracing life backwards to conditions which can be interpreted in terms of traditional physical and chemical conceptions. The fact that biology has not yet definitely extended itself into the details of what we are present call the inorganic world, is no argument for the impossibility of this extension. Meanwhile, however, we must never forget that biological interpretation extends over the whole field of our experience, however imperfectly in detail.

Schwab observed that Bohr's discovery that features of the atom, its stability for instance, were not reducible to classical mechanics was applied to descriptions of the complementary relationship between atomic physics and the features of the living cells. He quoted the biophysicist Delbruch who in 1949 explored the analogy between individual living organisms and molecules. This idea, which Delbruch said was due to Bohr, established a new relationship between physics and biology. Instead of aiming for a material explanation in molecular physics, Delbruch saw natural limits to the approach and the possibility of new territories in which laws may hold which involve new concepts only loosely related to those of physics. It was, he observed, more acceptable by the fifties, to claim that the detailed chemical structure of a living cell was operationally undefinable in terms of mathematical physics. Analysis could now be done "on the living cell's own terms" and theories should formulated without fear of contradicting molecular physics.

Schwab saw the extension of the holistic biological interpretation not only to the inorganic world but also to educational discourse. He was not alone.

In the thirties and the war years another synthesis was being debated - the terms on which Science would enter the liberal curriculum in mass secondary education.

Biologists, Scientific Holism and Curriculum Reform

Several reasons have been advanced by Jenkins (1979) and Fawns (1988) for the prominence of biologists in key roles in the advocacy of "Science for all" in schools in the thirties and forties in both England and Australia.

1. The argument for any new emphasis in the curriculum, particularly at that time, had to be made in terms of the subject's direct economic, social and intellectual value. This was the period of establishment of the curriculum foundation of mass Secondary Education. The economic significance to Britain in the thirties of increased agricultural productivity in the Dominions was one feature. The intellectual integration of plant and animal studies seemed to promise, at a macro level, a deeper appreciation of ecology and landscape, and at micro level, insights from fields such as genetics and virology which comprised a scientific foundation to medical and agricultural education.
2. Public health policy issues such as sex education, found to be deficient among the soldiers sent abroad in the first World War, as well as nutrition provided a ready made platform for a greater emphasis upon education in human and social biology. E.J. Hatfield in the preface to his text observed that perceived threats to Western Civilization often led to assertions that biology had a "special mission" to fulfil in secondary schooling. Amongst the unformulated ideas which underlay these concerns was the need to educate the citizenry about the scientific foundation to arguments for eugenics.
3. The physical sciences were held by prominent liberals to have nothing intelligent to say about a common humanity or social cohesion (Fawns 1987). Another curriculum invention of the thirties Clear Thinking, advocated by the Education for Citizenship movement to counter "extremist ideologies", was drawn from T.H. Huxley's nineteenth century common sense biological reasoning. From within the establishment, Julian Huxley (1932) wrote of the social value of biology which he claimed was more likely to inculcate an optimistic view of social progress, by virtue of the biologists' commitment to such principles as biological interdependence and an evolving and adaptable human nature, than was Physics where the physicists taught the law of entropy - of increasing disorder.
4. Changes to the economic and social-political milieux paralleled shifts in biological

science. The success of Marxist dialectic materialism on the grand scale in the Russian experiment confirmed for many scientists including Bernal, Haldane, Ashby and Turner the superannuation of laissez-faire liberalism and the success of government intervention in promoting the use of scientific knowledge for the common good of all humanity. Scientists, in the war years, in the wake of dramatic technical successes of radar and penicillin for example, were briefly encouraged to seek a higher profile in political discussions of social reconstruction and manpower planning.

5. The Associations of Scientific Workers, the politically active wing of the Association for the Advancement of Science in Britain and Australia were with notable exceptions led by biologists. In Australia the Association was an umbrella organization of younger scientists drawn particularly from the emerging fields of the biological and social sciences including education. Jean Moran (1983) found that in its short life in Australia from 1939-49 this group eloquently proclaimed the potential of science as a public resource both as a badge of utility and the key to good citizenship. Education rather than industry or politics has been an area in which scientists have been expected to exercise authority and influence. In the public campaign being fought by the Australian Association for professional recognition in the war years, leaders, like Eric Ashby (1946) and John Turner, in particular, often spoke from the political middle ground on curriculum issues not only between the physical scientists and the liberals, but also from between the experimental sciences and the social sciences (Fawns, 1988). The secondary teacher unions and the science teachers' associations were not yet established to promote the independent professional interests of teachers of school science.

Schooling in Scientific Holism

On his arrival in Sydney in 1938 Ashby found Botany in Sydney was still "heavily morphological and macro-ecological". Fifty years later Ashby recalled that he and Turner as young professors of Botany were "missionaries for experimental botany." Turner, the author of the first general science text in Australia and Chairman of the Web of Life Committee recalls that Cambridge Botany where he was trained had broadened and established a reputation for experimental work in the twenties. As a student, he was not himself caught up in the bitter and rigid separation of form and function between the phylogenetically obsessed morphology and physico-chemical plant physiology that occurred earlier elsewhere. However the solution suggested by the pioneer British ecologist, Tansley, to the teaching crisis in university botany in 1923, Turner felt bore upon the essential problems of curriculum reform in universities and schools. Tansley sought a broadly based elementary botany in the university which offered a logically related and effectively integrated treatment of form and function.

> If botany, as the science of plants, is to retain any meaning as a whole, somebody must retain the power of looking at it as a whole. And if, as teachers, we fail to keep touch with the newer developments, and are consequently no longer able to focus the whole subject from a viewpoint determined by current knowledge, this power will come to be possessed by fewer and fewer botanists, and the subject will definitely and finally break up into a number of specialised and unco-ordinated pursuits. Do we want that to happen? I think that most botanists would answer "No!" I do not think there can be any question that the most advanced research worker, as well as the student who never goes on to research, benefits substantially by having had a training which is at once the broadest and the most vital that is possible. As science continuously advances and necessarily specialises, the unexplored fields which lie between the traditional lines of research become of more and more relative importance. They cannot receive adequate attention - the student can, indeed, hardly become aware of their existence - unless his introduction to the subject is continuously informed by the widest outlook and the clearest apprehension of the essential relations of the phenomena of plant life.

Turner worked under Tansley's student, Godwin. In this apprenticeship in the academic politics of practical curricular reform at university level, Turner was as a young Professor aged 28 dealing with questions such as how to retain the old and accommodate the new, and how to retain the proven, in Tansley's terms to look at the whole, whilst being committed to advancing study in the new specialism. Turner and Ashby had training in both ecology and experimental botany, and were well prepared. Adaptability was a most desirable characteristic in a young professor in plant physiology in Australia in the thirties. Turner was expected to be a jack of all trades - field worker, conservationist, naturalist as well as experimental botany plant physiologist.

Turner felt, that "the movement of the human spirit", characteristic of the sixties, was inspired by advances in experimental biology, the most profound of which was the revelation of the structure of D.N.A. In this period the physicist Robert Oppenheimer reflected in a public address on the difficulties of Physics in the age of molecular biology.

> Five centuries ago the errors that physics and astronomy and mathematics were beginning to reveal were errors common to the thought, the doctrine, the very form and hope of European culture. When they were revealed, the thought of Europe was altered. The errors that relativity and quantum theory have corrected (in this century) where physicists' errors ... limited to a very small part of mankind.

However as we have seen, it was the reflections of Neils Bohr and others from the frontiers of modern physics that had, in the thirties, inspired confidence in an holistic explanatory method in Biology. The broader cultural appreciation of this biological reasoning was the key purpose which Schwab and Turner each proposed for the methodological reform of school biology in the sixties.

Jerome Bruner (1962) Director of the famous Woods Hole conference which promoted the American programmes of curriculum reform in the sixties claimed that he applied Bohr's idea to "the complementarity between the structure of knowledge and its instruction". In the process, it can be said Bruner established at that time the need for a theory of learning to mediate the interpretation of the structure of knowledge. Thereafter it became possible to deploy psychological theories to justify policies in science curriculum design.

However, Schwab and Turner saw the educational challenge as social rather than psychological. Their idealized teachers aided by a less dogmatic text would be concerned to reveal not only what they knew but how they knew biology and how they valued it. This reflected their commitment to developing intellectual judgment and moral agency through science education. The complementarity they proclaimed was between the new explanatory method and cultural development rather than between structures of knowledge and individual cognitive development (Schwab 1958).

Cultural Connections

To discuss the origin of the mechanistic view and its replacement by a holistic view requires considerably more study than has been carried out in cultural history of biology or education. Discussion of parallel movements in economics, history, biology and education is meant less to suggest a cause and effect relationship than to suggest that the parallels are not fortuitous. Biology and society have many points of interaction. Education is somewhat centrally placed to interpret both. A deeper understanding of the interconnections, particularly in terms of directions of influence, deserves more attention, if only because it may help us to understand our professional roles as science educators.

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Research In Science Education, 1988, 18, 276-282.

SOLID WATER IS DENSER THAN LIQUID WATER: STUDENTS' EXPERIENCES OF SCIENCE LESSONS IN FIJI

Srinivasiah Muralidhar

BACKGROUND

I had just finished observing a science lesson by a student-teacher in a secondary school. A group of girls from another class came and stood near the door, and I thought that they wanted to come into the laboratory for their next class. As I stepped out of the laboratory, one of the girls in the group said, "Sir can you tell us how phosphorus looks." I asked them why they were particularly interested in phosphorus. They said that they had just done an experiment on phosphorus. This puzzled me a little and I said to them, "If you have done the experiment, surely you must have seen phosphorus." One of the girls replied, "We did the experiment on the board." This incident happened many years ago, but the student's innocent statement left a deep impression on me, and I have often wondered as to what motivated the girls to approach a stranger with their concerns.

Such experiences prompted me to undertake a study, to look closely at the conduct of science lessons and students' experiences in science lessons in Forms 1-4, which is equivalent to Years/Grades 7 - 10.

EXPLORING TEACHING AND LEARNING

During 1987, I observed about 300 Basic Science lessons in seven secondary and five primary schools in Fiji. Data were gathered through a variety of sources. In this paper, I will illustrate how some of the data sources were used to explore students' and teachers' ideas about "heavy", "dense", "floating" and "sinking". Students are first introduced to these concepts in Year 8 under the Unit Floating and Sinking. These ideas are expanded further in Year 10 in the Unit Ships and the Sea.

Box 1 shows extracts from the transcript of a lesson in Year 10 (Unit: Ships and the Sea, Lesson: Why do ships Float?). The extract begins at the point where the teacher is referring to a question in the text: "Which is more dense, solid water (ice) or liquid water? Test it." Later in the lesson I spoke to groups of students to explore their responses to similar questions.

BOX 1 Extracts From Transcript of Lesson 202 SV10

(T: Teacher O: Observer B: Boy G: Girl)

T: Let us move on further. Which one is more dense - or which is more dense - solid water - that is ice - or liquid water?

B1: Solid water

T: solid water?

B1: yes

T: has got greater density?

B1: Yes

T: that is right - yes. Why would you say that solid one er... why would you say that the solid or the ice has got greater density? What you mean to say is okay - ice has got greater density than water - why do you say that? What is the reason behind it?

B1: because it is already solid?

T: What is the suggestion?

B1: because it is already solid and increases the weight

T: already solid - increases the weight? Who else? Why do you say that the density of ice is more - greater than liquid water?

B2: water - in the water, er... liquid particles separate

T: Okay - so, in other words, what has happened to those particles?

B2: (noise of truck drowns the answer)

(Observer speaking to one group)

O: What have you written for this question - which is more dense - soild water or liquid water?

G3: solid water

O: Um? which is more dense?

B2: Solid water

O: How do you know that?

B2: because solid er... when the time you( ) the solid, solid particles are all - all tightly held - liquid particles are far apart

O: Yah - but how will you decide which is more dense - solid water or liquid water? If solid water is more dense, what will happen if you put that soild water into water? What is another name for solid water?

B2: ice

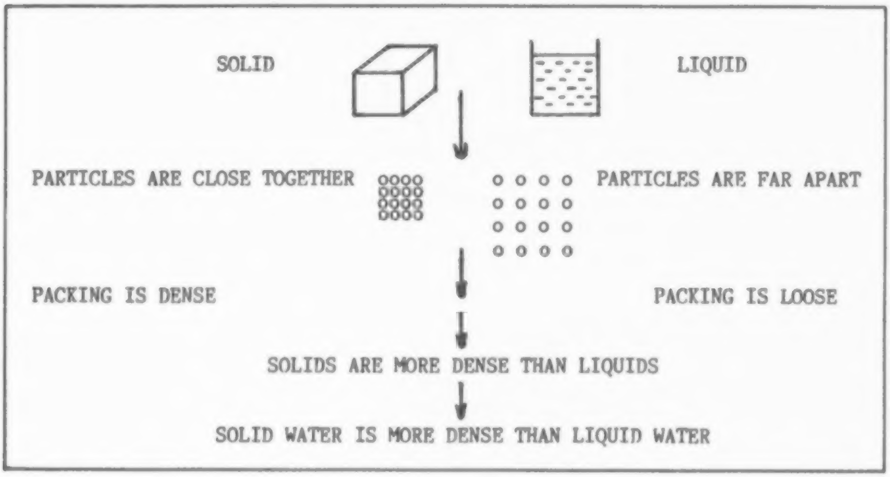
O: ice - okay. So, what you are saying is, ice is more dense than water

Analysis of the Transcript

The transcript revealed a number of interesting points. First, the responses and explanations given by the teacher and the students, seem to be influenced by the reasoning indicated in Box 2.

Second, both the students and the teacher held the view that ice is more dense than water, despite their experience that ice floats in water. Other observations that are not shown in the extracts were: when I moved away from the discussion of ice and water to Solid A and Liquid B, students were still thinking in terms of ice and water; they believed that the volume of a liquid will increase when a solid is placed in it; they took some time to realise that solid water and ice were the same.

Box 2 Reasoning


SOLID
LIQUID
PARTICLES ARE CLOSE TOGETHER
PARTICLES ARE FAR APART
PACKING IS DENSE
PACKING IS LOOSE
SOLIDS ARE MORE DENSE THAN LIQUIDS
SOLID WATER IS MORE DENSE THAN LIQUID WATER

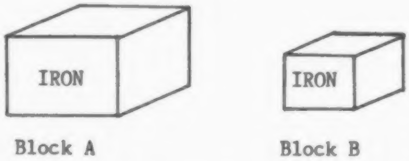
Diagnostic Questions

Having identified some of the difficulties students had, I decided to probe further, to determine the extent of the problem. With the permission of the teacher, I asked the whole class to answer the five questions shown in Box 3.

Box 3 Diagnostic Questions 1 - 5

Questions 1 - 4: Fill in suitable words in the blank spaces.

1. ________ is denser than ________.
2. ________ is heavier than ________.
3. Kerosene is less dense than ________.
4.



Block A is ______ than Block B, but both have the same ______.

Question 5: A, B, C, D are four solids.
A is denser than B;
B is denser than C;
C is denser than D.
Solid B floats in water.

(a) Which other soilds will certainly float in water? Explain.
(b) Will solid A float or sink in water? Explain.

Questions 1 - 3 were left open to cater for a variety of responses. Question 4 is similar to the ones in the Year 8 textbook, and Question 5 is an adaptation of a question from the same textbook.

Performance on Questions 1 - 4

The first four questions were also presented to four Year 8 groups and a Year 9 group in different schools. A comparison of the performance of the six groups is shown in Table 1.

Overall, the groups performed best on Question 3, and worst on Question 2. It is interesting that two Year 8 groups, PM08 and PG08, performed better than the Year 10 group SV10, on Questions 1, 3 and 4. Questions 1, 2 and 4 had a large variety of responses.

For Question 1, 22 percent chose brine - water combination as the response and these students were all from Year 8. This could be due to their recent exposure to the prescribed demonstration activity in which they observe the difference when an egg is placed in water and then in brine. The only group that chose the liquid - solid, ice - water and water - ice combinations was the Year 10 group, SV10. This must have been the result of the lesson they had just before answering the questions.

Table 1 Performance on Questions 1 - 4

Schools	(Primary	)	(	Secondary		)	
Groups	PM08 n=39	PG08 n=25	SM08 n=37	SS08 n=28	SS09 n=27	SV10 n=34	Total 190
QUESTION 1							
Variety of Responses	12	12	16	13	21	19	65*
Acceptable Responses	33	17	16	17	12	12	107
% of Accep.Responses	85%	68%	43%	61%	44%	35%	57%
QUESTION 2							
Variety of Responses	15	14	23	20	24	22	81*
Acceptable Responses	0	0	6	1	2	3	12
% of Accep.Responses	0%	0%	16%	4%	7%	9%	6%
QUESTION 3							
Variety of Responses	3	5	4	4	8	5	12*
Acceptable Responses	39	25	36	25	22	29	176
% of Accep.Responses	100%	100%	97%	89%	81%	85%	92%
QUESTION 4							
Variety of Responses	16	9	23	21	19	19	71*
Acceptable Responses	22	14	17	12	17	17	99
% of Accep.Responses	56%	56%	46%	43%	63%	50%	52%

(* This is not the total for the groups: many group-responses overlap)

Only six percent of the students gave acceptable responses for Question 2. The majority of the responses were suitable for question 1. This indicates that students may have been thinking of "denser" when they were looking at the word "heavier". Perhaps, the difference is not clear to most of them.

The most popular response to Question 3 was "water", followed by "oil" and "brine". This is not surprising because kerosene floating on water, is a common experience for most students.

For Question 4, 58 percent of the students used the words "heavier/heavy" and 36 percent used "bigger/larger/big" for the first blank. For the second blank, 21 percent wrote that the blocks have the same "density", and surprisingly, an equal number wrote that they have the same "weight". About eight percent said that the blocks have the same volume. The seven students who wrote that the blocks have the same "mass", were all from the Year 10 group SV10. Students in Years 8 and 9 may not be familiar with the term "mass".

The variety of responses for Question 4 was 71, and even the acceptable responses varied in quality. Again, the quality of responses given by the two Year 8 groups PM08 and PG08, was better than that of the Year 10 group SV10.

Performance on Question 5

In addition to the Year 10 group SV10, two Year 8 groups also responded to Question 5. Table 2 summarises the performance of the three groups.

Table 2 Performance on Question 5

Group	PG08 n=25	SM08 n=37	SV10 n=34	Total 96
Part (a)				
Correct Answer:Correct Explanation	10	1	4	15
Correct Answer:No Explanation	1	1	3	5
Correct Answer:Wrong Explanation	4	7	5	16
Incorrect Answer	10	20	21	51
No Response	0	8	1	9
Part (b)				
Acceptable Response	0	0	0	0
"A will sink"	14	17	17	48
"A will float"	9	9	16	34
Other Response	2	3	1	6
No Response	0	8	0	8

Of the 15 students who gave the correct answer and correct explanation for Part(a), 10 were from group PG08 and only four from group SV10. No one gave an acceptable response for Part(b). Forty eight students wrote that "A will sink", and 13 of them gave reasonable explanations. Of the 34 students who wrote that "A will float", 16 argued that "A is denser than B, and if B is floating, A should float". Although Question 5 was very similar to the one in the Year 8 textbook, students, including the ones in Year 10, performed poorly.

DISCUSSION

The analysis of teachers' and student's statements during a lesson, and students' oral and written responses to diagnostic questions enabled the identification of a number of misconceptions and difficulties they have about concepts such as "heavy", "dense", "floating", "sinking", "weight" and "volume".

Students' learning of some of these concepts as the secondary level have been investigated from different perspectives by Rowell and Dawson (1977a, 1977b), and Hewson and Hewson (1983) and Hewson (1986).

An important feature of this investigation is that it was not planned - rather, it developed during a lesson in Year 10, and subsequently involved groups of students in other schools.

Students use words like "brine" and "solid water" freely, but they have difficulty relating them to substances they are familiar with. Teachers and designers of textbooks must make the connections clear to the students.

It may be easier for students to comprehend the difference between "heavy" and "dense", or "weight" and "volume", if they are exposed to experiences that are deliberately planned to clarify the distinction. White (1988) provides examples of how teachers can plan for the formation of useful episodes in the classroom.

The quality and variety of questions students are exposed to are also important in promoting the understanding of concepts. Unfortunately, such questions are lacking both in the Basic Science texts and in classrooms.

An important outcome of this intervention was that teachers became aware of the difficulties they and their students have in dealing with important concepts. The positive feedback from teachers reinforces the usefulness of the collaboration between teachers and researchers in bringing about improvements in teaching and learning.

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HELPING STUDENTS LEARN IN CHEMISTRY

Brendan Schollum

INTRODUCTION

There is research evidence from within New Zealand (e.g. Carr, 1984; Burns, 1982) and overseas (e.g. Johnston et. al., 1971) describing the nature and range of difficulties senior students in secondary schools have in learning Chemistry. There is less evidence described in the research literature, of strategies used to help students learn Chemistry. There are, however, many teachers who are intuitively aware of many problems faced by learners in Chemistry (and indeed, in Science) and some of these teachers often devise realistic strategies for helping overcome some of the problems encountered. Most often, these strategies are not formalised, nor made public and shared with other teachers in particular, nor are the teachers' efforts evaluated appropriately.

From another perspective, there is now the powerful intent and persuasive evidence from the PEEL project (Baird and Mitchell, 1986) showing how teachers can work together in helping students learn, as well as reflecting deeply on the processes involved, and their outcomes. The vivid, honest account of the PEEL group at Laverton High School in 1985-6 was very helpful in mounting an inservice course for Chemistry teachers in Auckland in 1988.

As the research co-ordinator, the author wished to work alongside a small group of energetic, interested teachers to formalise effective strategies used in their classrooms, and communicate these to others. It was hoped that pairs of teachers in schools would work together for mutual support, but individual teachers were welcomed also. The intent and desired outcomes of this Action-Research Project are shown in Table 1.

TABLE 1
INPUT AND DESIRED OUTCOMES OF THE IMPROVING THE LEARNING OF CHEMISTRY PROJECT

	Students	Teachers	Research Co-ordinator
INPUT	Participation in surveys, practicals, in an open way. Be prepared to talk about own learning and learning processes	Meetings Reading research papers Devising strategies	
		Implementing	Monitoring Evaluations
		Evaluations	
DESIRABLE OUTCOMES	More effective learning in Chemistry including: a clearer understanding of key processes and strategies used in learning greater independence and self analysis in learning	Professional development	
		Feedback of own teaching from peers. Input to teacher inservice courses	More effective in teacher education with research data gathered

Thus, early in 1988, a 12 hour (6 x 2 hr) inservice course was offered to local Chemistry teachers using the above rationale. As a result of the course, it was hoped that teachers would be prepared to carry out some action-research of their own making in their own classrooms. Fifteen teachers enrolled in the course, which involved four input sessions and two workshop sessions where possible research proposals were discussed and clarified.

INPUT SESSIONS

1. Identifying Effective Learning Strategies

The purpose of this session was to identify, in groups, sets of effective learning strategies in Chemistry and to identify limitations to the implementation of these strategies. Examples provided of effective strategies included:

- students having receptive attitudes to Chemistry;
- awareness by the teacher of students' existing understanding and knowledge so that learning goes from the familiar to the unfamiliar;
- students perceiving the subject as relevant and useful to everyday life;
- adequate physical resources for practical work;
- consistency of usage in chemical language;
- teachers keeping abreast of changes in theoretical perspectives.

The latter part of the first session was spent with the teacher participating in an exercise as described by Fensham (1984). This exercise, involving prediction, observation and explanation helped focus on problems students have in Chemistry; for example, rationalising or manipulating observations to fit with predictions.

2. Problem Solving

The term "problem-solving" was clarified and defined including how it differs from low-level mental exercises commonly found in Chemistry texts. Time was spent determining examples of problems that would be worth solving in the senior school; for example:

Why does soap remove some stains but not others?

Why does food "go off" more slowly in a fridge than in the open?

Considerable time was spent in investigating problem-solving strategies through the work of Larkin and Reif (1981). This led to some immediate classroom trials as will be shown.

3. Mastery Learning

The focus of this session was analysising the work of Bloom through his "Two-sigma" paper (1983), and the potential of mastery learning in Chemistry. After the expansive and divergent thinking implicit in the previous session, this session had a much narrower focus of attention; i.e. Bloom's evidence of how he and his colleagues researched how students in classroom situations could attain the high levels achieved in one-to-one tutoring.

The teachers evaluated the purpose, desirability and application of mastery learning in senior Chemistry, and focussed on one section of the senior course - Acid-Base Chemistry.

4. PEEL Findings

In this session, the background to PEEL, the processes and strategies used, and some of the findings were outlined. Examples of concept mapping, and reverse questioning, were trialled in a Chemistry context.

This session had quite an impact. Continual reference to the Laverton High School experience (Baird and Mitchell, 1986) with its vivid examples and accounts of teachers' and students' thinking about learning was helpful in a variety of ways: the energy of the teachers involved, their honesty and analyses of their own actions, and the reaction of the students. The success of PEEL has been described by Baird, Mitchell and Northfield (1987).

5,6 Workshops

These sessions allowed teachers to raise issues of greatest concern to themselves, to talk and formulate possible further action. But because there were such demands on the teachers (e.g. New Zealand's first Focus on Science and Technology Week was about to begin) and the end of term was approaching, specific research proposals were not clearly developed. For some, the course had already served its purpose - exposure and discussion of several issues central to effective learning.

Over the next two months several research proposals did crystallise. Two guiding principles at this stage were those of "ownership" and "high morale". Guy Claxton at a recent seminar at Auckland explained his meaning for these terms. Teacher change towards more effective teaching/learning is more likely to occur if the teacher can make some actual claim to ownership of the change, and if the teacher's morale is high; that is there is not co-ercion or guilt associated with the change. The following proposals, and actions are those of teachers involved in the course.

RESEARCH PROPOSALS

1. Acid-Base Theory

As Carr (1984) has shown, acid-base theory is currently surrounded by confusions and traps for the unwary. One source of confusion is the way teachers and teacher educators use aspects of the models developed by Arrhenius and Lowry-Bronsted too readily.

Another source of confusion is that of the terms "strong" and "weak" as applied to acids and bases. The Lowry-Bronsted model shows a relationship between acids and their conjugate bases. That is, the conjugate acid of a strong base is a weak acid model; e.g. the conjugate acid of hydroxide ions is water.

But consider the converse; the conjugate base of a weak acid (e.g. ethanoic acid) is a strong base (ethanoate ion) this is clearly inaccurate.

This teacher believes that we should be using these terms -strong, weak and negligible - in describing or classifying both Lowry-Bronsted acids and bases, and provides many examples.

2. Mastery Learning and Acid-Base Chemistry

Two teachers at one school decided to write and trial a ten-hour unit on Acid-base Chemistry at Form 6 (Year 11) using mastery learning. They decided that the unit would include:

a) a short pretest leading to remedial exercises on Chemical language/formulae for any pupils who were not able to answer several items accurately. Other items on general properties of acids were part of the formative assessment.

b) a clear list of objectives of the unit for all students at the beginning of the unit. Students were expected to use this as their guide for learning.

c) three short, mid-unit mastery exercises; students would have extension exercises or remedial exercises depending on their achievements.

d) practical exercises for students to demonstrate techniques involved in accurate volumetric analysis; e.g. making a standard solution, pipetting. These would be further tested in a more formal practical test.

The teachers are working towards high mastery by their students in this topic rather than accepting a more normal distribution of achievements as has happened previously, when they used an end of unit test as the main assessment instrument. But as well the two teachers wanted to have their students reflecting on their own learning and have adapted the Learning Checklist (Baird and Mitchell, 1986, p. 77) to be used alongside two sections of this topic.

3. Problem solving and Stoichiometry

After the session on problem solving, one teacher who was just beginning the topic "The Mole Concept" with her sixth Form class, decided to explore her students' ability to solve problems without her usual highly structured examples and exercises. In the first lesson she set the following problem:

> "Given that hydrogen and oxygen react to form water, how much of each would you need so there is no hydrogen or oxygen left over".

Individuals worked on the problem for about ten minutes before there was any class discussion. The important issues of balancing an equation, comparing mass values, or volumes were raised, and discussed fully. The impact of this brief experience and the reaction of her class led her and a colleague to pursue this apporach further in the unit; one obvious result was the increased mental activity by the classes during the unit. The class achievements were improved on previous years, but whether this was due to better learning or better students was not clear. Certainly these teachers are determined to trial a similar strategy next year but be more formal and meticulous in their record keeping.

4. Group Work in Chemistry

Two teachers, who usually set assignments and learning activities that are directed at individuals in a class, wished to explore the value of small group work in Chemistry. This technique had been used in some practical activities but not in other class tasks.

The teachers were interested to see what responsibilities the groups of students accepted, and the strategies they adopted.

DISCUSSION

Although the motives for enrolling in the course were varied, all the teachers appreciated the opportunity to meet with colleagues who were also interested in helping their students learn. So far, half the teachers have decided on particular strategies to be used in their classes, at least in particular topics. But during the course itself, and in the intervening two months some critical issues have arisen and are as yet unresolved.

The first of these relates to why any teacher should be involved in the first place. The fact that teachers are prepared to commit time and money, possibly without their principals being aware of this commitment, for professional development is admirable. Unlike many countries New Zealand has been slow to develop appropriate post-graduate courses for teachers. Fortunately links between Colleges of Education, Polytechnical Colleges and Universities are growing stronger. Courses in Maths Education which are joint courses of the College of Education and the University, have recently been approved as an example, but equivalent courses in Science education should be seen as a priority in all main centres.

The second issue relates to the procedures of assessment within New Zealand in the Senior school. At present there are mainly external examinations at the end of Forms 5 and 7 (Years 10 and 12), with Sixth Form Certificate, SFC, internally assessed. A school has a pool of grades to be allocated to SFC, from their students' performance in School Certificate, Form 5. The anomaly is this: despite the decision and competence of a particular teacher in a particular class at Form 6, at present that teacher still has a particular set of grades available to allocate to her/his students. Thus teachers and students who work conscientiously to improve the students ability to learn independently, and effectively may never see that improvement acknowledged publicly. Fortunately, there are currently some trials of stand-alone moderation at SFC.

Finally, one of the important factors determining the success of PEEL was the regular meetings, and the group support that developed. In a similar way, it is vital for continued morale, evaluation and professional development that this group meets again and this is planned. It is also pleasing to see that four of the group will present their developments at the 1988 NZ Science Teachers Association Conference. One key objective, that of raising the confidence of teachers to describe their innovations to fellow professionals, is being realised.

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MISLEADING ILLUSTRATIONS

Doug Hill

INTRODUCTION

Diagrams and drawings are not always easy to interpret (Lowe, 1987). The reading process is complex and involves making decisions about the context of the illustration, the meaning of the elements involved and the nature of their relationship.

Many science concepts are abstract and students are expected to develop them in the absence of first hand experience. In the field of chemistry diagrams are often used to supplement descriptive text and mathematical models. Such illustrations represent attempts to communicate particular information in a more concrete way and to develop effective mental models (Winn, 1988). However, the communication process also involves the learner as an interpreter and thus the ideas which the learner receives may not be the ones the illustrator wished to convey. Such mismatches may be considerable in classrooms in which visual literacy is neglected and students attend to such illustrations uncritically.

Visual literacy involves "reading" diagrams and pictures and representing ideas by drawing. Scientific illustrations have particular characteristics which parallel the distinctive features of scientific writing (Lowe, 1986). They have both a pictorial and a scientific dimension. If either component is faulty then the illustration may be misleading.

It appears that a number of texts in common use in Australian schools contain diagrams and drawings which may mislead the naive reader. For example, in the field of particle theory in elementary chemistry texts the following "errors" are common:

1. solute particles are over-represented in solutions;
2. the extent of expansion by solids when heated is greatly exaggerated;
3. liquids are represented in a way which suggests that they are readily compressible;
4. the decrease in the density when a solid is melted is excessive;
5. the decrease in density when a liquid changes to a gas is under represented.

Lowe (1988) has argued that "When the author of a scientific diagram is engaged in its construction, the salient features of the subject matter must be identified and depicted appropriately. In addition, important relationships between the entities constituting the diagram must be represented in an enlightening, unambiguous and readily discernible manner" (p. 35). Frequently the elements of the diagram are represented in simple outline or by symbol and processes or relationships shown by joining these with lines and arrows or placing groups of elements in boxes.

In the case of the kinetic model of matter, the particles are commonly represented as dots, spheres or circles and the spatial relationships between them shown in either two or three dimensions. The conventions commonly observed include an assumption that any picture is a snapshot taken at a particular moment in time; that equal areas represent equal volumes under the same conditions and that the size of particles remains constant throughout changes of state. Such illustrations are thus not as unproblematic as many science teachers assume. Lowe (1987a) has argued that students may need systematic help if they are to develop the skill required to interpret such material.

TABLE 1
Responses to the Diagrams in Science Test by question and alternative.

Question	Alternative			
	(i)	(ii)	(iii)	(iv)
1	27*	15	17	NA
2	15*	31	9	NA
3	27	8	8	15*
4	4	34	17*	NA
5	36*	11	11	NA
6	6	7*	43	NA
7	23*	23	5	6
8	6*(a)	31(b)	NA	NA

* Preferred alternative
(a) 1 or 2 circles shaded
(b) 3 or more circles shaded

TABLE 2
Percentage of Responses Consistent With Common Text Book Errors

Common Error	% Response
1 (Q8)	83.8
2 (Q7)	59.6
3 (Q2)	72.7
4 (Q1)	54.2
5 (Q3)	74.1

In this study it was argued that students are likely to hold misconceptions which are consistent with common errors found in science textbook illustrations. A multiple choice test was developed to test this hypothesis. The test consisted of eight items, each of which required an explanation of the reason behind the particular response. This test was trialled with a group of twenty science students undertaking the Diploma of Education program at Riverina-Murray Institute of Higher Education (RMIHE). Five of the students were later interviewed to follow up the explanations they provided to justify their responses. This information was used to revise the test.

The revised test was subsequently administered to fifty nine first year science students at RMIHE studying a compulsory chemistry subject in the autumn semester.

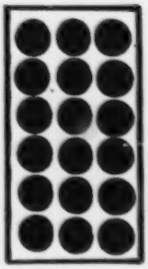
The results obtained are shown in in Tables 1 & 2.

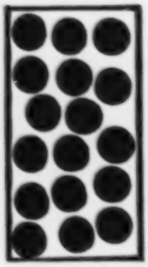
DISCUSSION

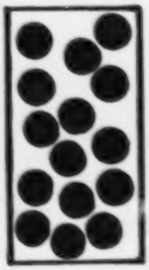
The responses to individual questions are not as informative as the explanations offered for the particular responses.

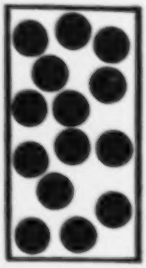
Question 1 was phrased as follows, with supporting diagrams showing molecules in equal volumes:

A petroleum wax melts at 70°C. The diagram shows the arrangement of the wax molecules at 68°C. Which diagram best respresents the most probable arrangement, at a particular instant in time, in a sample of the melted wax at 72°C? Tick one alternative.







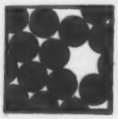


Respondents were asked to write explanations for their reasoning.

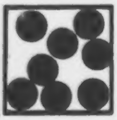
Question 1 was related to common error 4. The density of most solids decreases only by a few percent on melting. Those students who selected alternative (i) usually reasoned that the number of particles had to be approximately the same. Those selecting (ii) frequently argued that alternative (i) "looked like" the distribution of particles in a solid and (iii) like a gas therefore (ii) must be the liquid. Those selecting alternative (iii) argued that the molecules appeared random/disordered or that the bonds were broken and the molecules were free or that the average distance between them had increased.

Question 2 was presented as follows.

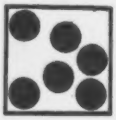
Which of the following diagrams best illustrates the spacing of molecules in a liquid?



(i)



(ii)



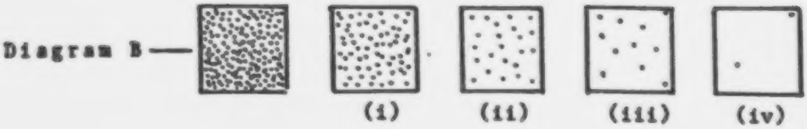
(iii)

As with Question 1, respondents were asked to explain their reasoning.

Question 2 was related to common error 3. Most students simply gave a general description of a liquid in terms of a reduction in order from that of a solid and stated that the alternative they selected "looked like" a liquid. There were no attempts to relate the diagrams to the macro behaviour of liquids.

Question 3 was presented as follows and an explanation was also required.

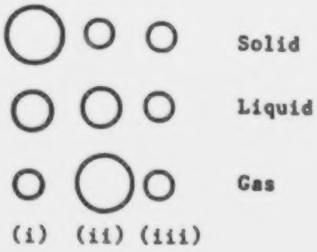
The petroleum wax boils at 230°C. Diagram B shows an arrangement of wax molecules at 228°C. Which diagram could represent the most probable arrangement, at a particular instant in time, in a sample of wax vapour at 230°C at the same pressure? Tick one alternative -



Question 3 was related to common error 5. Most students gave a qualitative description of a gas in terms of larger distances between molecules but gave no indication of any quantitative thinking. The vapour formed when a liquid boils at atmospheric pressure is usually less than 1% of the density of the liquid.

Question 4 was:

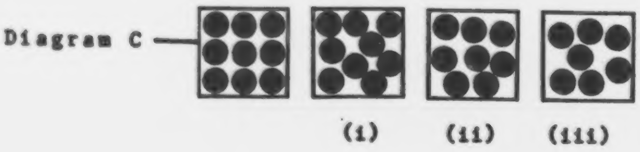
Imagine the wax molecules in solid, liquid and gas could be represented as spheres. Which set of diagrams would best represent the molecules under these conditions? Tick one alternative -



Question 4 was concerned with the idea that particle size remains constant throughout the change from solid to liquid to gas. The majority of students seemed to confuse size of molecule with the volume they effectively occupy with increased kinetic energy.

Question 5 was:

Ice floats on water. An arrangement of water molecule in ice is shown in Diagram C. Which diagram could best represent the most probable arrangement of water molecules in a sample of water at 3°C? Tick one alternative -



Question 5 was concerned with the relative densities of ice and water and how this is related to the relative packing of particles. Most students explained their response in terms of the number of particles present without direct reference to density.

Question 6 was concerned with the increase in volume of a fixed mass of gas at constant pressure, when heated from 100°C to 200°C. The majority of students selected the alternative which showed the largest increase - double the volume. Few of these students would have had any difficulty in carrying out this task as a numerical calculation.

Question 7 was related to common error number 2. It required students to select the alternative which showed the length of a copper bar which had been increased from 20°C to 25°C. Edge & Dirks (1983) have claimed that it is important for science students to have an appreciation of the order of magnitude of any calculation or change. They developed "Fermi problems" which required students to make simplifying assumptions and estimate relevant physical properties. Students selecting alternatives (i) & (ii) mainly did so on qualitative grounds and did not employ this kind of reasoning.

Question 8 was presented as follows:

The series of circles below represents part of a dilute (2M) aqueous solution of ammonia.

Show the relative distribution of water and ammonia molecules in this solution by shading in circles to represent ammonia and leaving those which represent water unshaded.

O O O O O O O
O O O O O O O
O O O O O O O
O O O O O O O

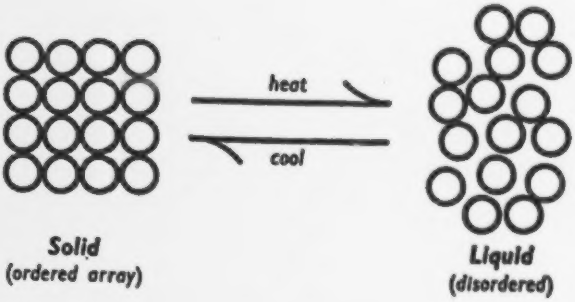
Question 8 was related to common error number 1. Only three students gave an appropriate quantitative explanation of the relative proportions of water and ammonia molecules. Many students commented on the need for a uniform distribution of solute in a solution, an aspect depicted in textbook diagrams. Other reasoning included -

> "Two roles of ammonia (34g) per litre means there will be a lot more water molecules."
>
> "There would only be a relatively few ammonia molecules which would be uniformly spread about."
>
> "Only one would be shaded as it is a very dilute solution."
>
> "Two ammonia circles are shaded because it is 2M."

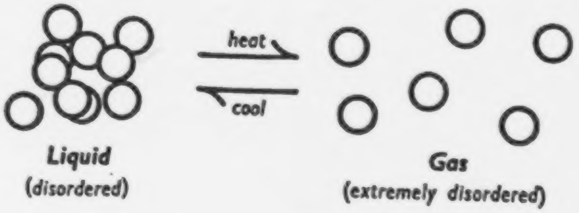
CONCLUSION

The responses and the reasons given for those responses suggest that many of these first year students were not able to read and interpret diagrams in a critical manner and recognise their limitations. Rather, they depend on a qualitative global appreciation of the relationships involved and do not distinguish between the diagram and the model it represents.

The overall pattern of responses on the test was consistent with the common errors identified in textbook diagrams. Such diagrams (see those which appear below) are notably qualitative and do not attempt to accurately portray relationships quantitatively. It appears as if such diagrams represent reality for many students. This finding has important implications for science teaching because it is known that the conceptual model held by a learner influences subsequent learning.



Structure of solids and liquids.



Structure of liquids and gases.

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SOME STUDENTS' BELIEFS IN MECHANICS - A THIRD WORLD VIEWPOINT

Beno Boeha

INTRODUCTION

The early natural philosopher, Aristotle distinguished between "forced" and "natural" motion. For Aristotle, forced motion was maintained by forces such as air around the projected body. This idea of force is similar to the notion that force is in the body, and pushes the body in the direction of the motion. This view was widely held by the 14th Century Parisian physicists headed by Buridan.

Recently a nubmer of studies have highlighted the substantive aspects of children's and adult's thinking concerning Buridan-type ideas/beliefs. Some of these studies include: Viennot (1979), Osborne and Gilbert (1980), Watts and Zylbersztajn (1981) exploring aspects of the concept of force; Saltiel and Mulgrange (1980), Trowbridge and McDermott (1980) about velocity; Nassbaum and Novak (1976), Gunstone and White (1980) about gravity, and so on. Recently Pfundt and Duit (1988) have updated a bibliography which now contains more than 1500 research articles on children's and adults' ideas/beliefs in different areas of science subject.

The ideas/beliefs have been given a variety of names such as "naive conceptions", "spontaneous ways of reasoning", "conceptual inventories", "naive beliefs", "naive knowledge", "intuitive physics", "misconceptions", "childrens' beliefs", "alternative frameworks" and so on. In Australia and New Zealand, the most common description for these beliefs has been "children's science" (Osborne, 1980a; Gilbert, Osborne and Fensham, 1982; Osborne and Freyberg, 1985) although adults tend to hold this idea also.

This paper reports some beliefs in mechanics, in particular about the topic of force, held by National High Schools (NHS) year 11 physics students (aged 16-17) in a third world country: Papua New Guinea.

METHOD

The data reported in this paper are one part of a larger study. This larger study required a mixture of pencil and paper and interview instruments similar to the Interview-About-Instances and Interview-About-Events used by Osborne and Gilbert (1979, 1980a). The instruments were presented in the form of diagrams on separate cards, by means of a line drawing. The questions on the cards asked "Is there a force on (the object?)", and asked to identify this force(s). This question was repeated until the subject said: "I cannot think of any more force(s)". Then the subjects explained their reasons for the force(s). The content of subjects' reasons formed "students' beliefs". Data from two of the instruments are reported here: a softball in the air and a man standing on the moon.

The purpose of the instrument was to probe students' beliefs about natural phenomena that they bring with them to science classrooms. The instruments were administered to students at the end of the second week of the 1986 academic year.

One of the four NHSs was randomly selected for this study. Students coming from Provincial High Schools to Grade 11 at the selected NHS were randomly assigned to six different classes. The interviews were conducted individually with all subjects in one randomly selected class. Their reasons from two of the interview instruments on the topic of force are reported here.

RESULTS

Table 1 below shows a broad categorization of students' beliefs about forces acting in two different physical situations. Situation 1 is about the trajectory of a softball. Stituation 2 is about a man standing on the moon.

TABLE
Broader Categorization of Students' Beliefs about
Forces acting in two different physical situations (n=22)

Physical Situations		Broad Categorization	%	(No. of Students)
1. SOFTBALL	1.	Yes, forces: reasons judged complete and correct (Newtonian)	0.0	(9)
	2.	Yes, forces, reasons judged partly correct and complete	45.0	(10)
	3.	Yes, forces reasons judged incorrect	50.0	(11)
	4.	Yes, forces or no forces: don't know the reasons	5.0	(1)
2. MOON	1.	Yes, forces: reasons judged complete and correct (Newtonian)	0.0	(0)
	2.	Yes, forces: reasons judged partly correct and complete	45.0	(10)
	3.	Yes, forces reasons judged incorrect.	50.0	(11)
	4.	Yes, forces or no forces: don't know the reasons.	5.0	(1)

SITUATION 1

In Situation 1, no student gave a response judged to be complete and correct, but 45% of students (10 students) believed that there were either two, three or four forces acting on the softball. Of these 10 students, two believed that there were two forces on the ball: force in the direction of motion (shown by an arrow) and another going down.

There was a force in the direction of the arrow because:

> "the man had pushed it with the bat to make it move".

There was a force coming down because:

> "when it reaches its potential...then the ball drops down due to the force..."

Another two students believed that there were three forces acting on the ball: force in the direction of motion of the ball, air pressure going backwards and gravity force going slightly forward in a curved path. There was a force in the direction of the arrow because:

> "the man hit the ball".

There was air pressure going backwards because:

> "the ball is travelling through against air pressure, therefore, to stop the ball to travel any further there is air pressure acting against it".

The gravity force was acting forward in a curved path because:

> "the ball cannot go any further and any weight that is not supported by anything can fall down. That is due to gravity, but in the curve like direction but not straight down".

Another three students also believed that there was gravity pulling the ball forward in a curved path. In addition they believed that there was a force by the batter when he hit the ball but no force by the man at the point shown, but there was the force of the air pressue coming downwards. The air pressure was coming downwards because:

> "the weight is above the ball so air pressure is just acting downwards".

The gravity acts forward in a curved path because:

> "the force which the ball had when it went up had a little bit forcing it there so when gravity acts on it, it doesn't come down directly but it goes sort of diagonally before it hits the ground".

Another student believed that there were four forces acting on the ball: force in the direction of motion of the ball; force in opposite direction; force going straight up and gravity coming straight down. There was force in the direction of motion of the ball because:

> "there is a force by the man batting".

There was a force in opposite direction of motion because:

> "when the man hits the ball it won't go forever and ever but in the end it will have to come to the ground".

There was force acting on the ball upwards because:

> "when the man applied the force to hit, the ball will fly in the direction of arrow, but the force then will act on the ball and it will go straight up ... not straight up but side ways".

The final student in category 2 (Situation 1) believed that there were three forces acting on the ball: force in the direction of arrow (motion of the ball); force in opposite direction and gravity force. There was a force in the direction of motion of the ball because:

> "the ball is in motion so it has to have some force in order to move."

There was a force going in opposite direction of the motion of the ball because:

> "if there was no force going backwards the ball will continue moving in the forward direction, that is, straight ahead ... so the force is stopping it to slow down and the downward force is slowing it down...".

Furthermore, there was gravity force which acted on the ball because:

> "it is acting straight down, but it is not very powerful, so its a bit weak, so the force of the ball which it comes from its moving more powerful than this one (gravity), so it has to slow down when it falls down a bit, the gravitational force push it down it will have to go not really direct but go up a bit then go down slowly".

The final student in category 2 (Situation 1) believed that there were four forces acting on the softball ball: force by the batter in the direction of motion; force of gravity pulling at about 45° forward; wind in opposite direction of motion and weight of the ball acting straight down. There was a force by the batter in the direction of motion of the ball because:

> "when the ball was thrown at him, he used his strength to hit the ball so the force was exerted onto the ball so the ball moved ahead, so the force applied by the man using his energy, so the force is still there...".

There was gravity force pulling the ball at about 45° forward because:

> "the energy applied onto the ball is still on the move and when the gravity act upon the ball then it starts to lose the energy and the force applied by the man, so it falls at an angle of 45°".

There was the weight acting downwards because:

> "if there was no weight, I guess the ball would fly up and float in the air. The weight of the ball makes the ball fall ... but I don't know what weight is".

In category 3 (Situation 1), 50% of students (11 students) believed that there was either no, one or two forces acting on the softball ball with reasons judged to be incorrect. Of these 11 students, three believed that there was a force in the direction of motion of the ball because:

> "the man was swinging the bat and hit the ball".

Another student believed that idea because:

> "the force was ... potential energy ... energy changes from the previous to ... kinetic energy applied and the ball moved".

Another student believed that there was no force on the ball because:

> "as the ball goes up the forces are cancelled out ... the ball has the potential force but it has kinetic force applied to it and as it goes up ... the potential force from the ball is converted to kinetic force".

The next three students believed that there was a downward force in curved path because:

> "as the ball goes up to its height there is less force so it loses its kinetic energy and it starts slowing down so it starts to drop back to the ground".

The final three students in category 3 believed that there was a force in the direction of the motion of the ball because:

> "the force applied to the ball is still moving it in the direction of the arrow but it will fall sooner or later downwards in a curve".

In category 4, the only student believed that there was:

> "something that pulls the ball to the ground, something like the force that pulls the ball towards the ground..."

She could not think of any more precise reason.

SITUATION 2

In situation 2, no student gave a response judged to be complete and correct, but, in category 2, 45% of students (10 students) believed that there were one or more forces acting on a man on the moon. Of these 10 students, five believed that gravity force acts on a man standing on the moon because:

> "the gravity pulling things towards it, towards the centre of the moon".

Four students believed that gravity acts on the man because:

> "if no force of gravity on the man, he would be floating, so there is little amount of gravity that helps the man to stand up on the surface of the moon".

Another student believed that there were both gravity and outward forces acting on the man because:

> "to keep him standing straight, his weight and the gravitational force is acting on him".

In addition, there was an outward force because:

> "if the forces are acting inwards only then his body may be crushed in, so there are forces acting outwards".

In category 3, (Situation 2) eleven students believed that there was no force acting on the man on the moon. Five of these students believed this because:

> "there is no gravitational force on the moon".

Three students believed this because:

> "there is no gravitational force, he is supposed to be floating but he is using some sort of machine to keep him on the moon".

One student believed that there were forces acting upward, downward and side to side because:

> "on the moon there is no force there. The only force that is strong is the force going upwards due to atmosphere on the moon".

There was a downward force because of:

> "no gravity on the moon so the force is not strong coming down".

While the side to side is "to keep the man in shape". While two students believed this because:

> "we study that there is no air on the moon so there is no force acting on the moon".

In addition, one student believed that there was a force but she did not know the reason for the force (category 4).

DISCUSSION

The purpose underlying the reporting of these data is to indicate students' beliefs about two physical situations involving forces in a sample of students in a third world country. It is important to note that the beliefs reported here come from students who have been taught general science for the previous four years in PHS.

No students indicated correctly all forces involved in any of the situations. Interestingly in situation 2 about 50% of students generally believed that gravity force acts on objects towards the centre of the moon. In contrast, about 41% of students believed that gravity was pulling the softball in a curve-like path. In addition, 77% of students believed that there was a force in the direction of the motion of the ball. Some students' beliefs might be considered as children's science (Osborne, 1980 a, b; Gilbert, Osborne and Fensham, 1982). Other beliefs might be considered as vague "Scientists' Science" (Osborne, 1980a).

Under the umbrella of children's science there was evidence of students' beliefs that are specific to direct human experience. These were identified by physical contact and mental coercion. These have been described as "human-centred" (Osborne 1980 a, b; Gilbert, Osborne and Fensham, 1982; Gilbert, Watts and Osborne, 1982) beliefs. For example,

> "the man had pushed it with the bat...". (Softball)

In addition, human-centred beliefs have shown to be related to the belief that if there was no obvious external agent of force exerted on an object then there was no force on the object. For instance,

> "there is no gravitational force, he [is] supposed to be floating...". (Moon)

In recent studies children have shown beliefs which imply characteristics of humans or animals for non-living things: endowing objects with human or animal characteristics (Osborne 1980 a, b; Gilbert, Watts and Osborne, 1982). For example,

> "the force which the ball had when it went up had a little bit forcing it there...". (Softball)

Related to the above belief, many students in this study believed that forcing oneself to do something required action. That is, students endowed moving objects with a force. For examples,

> "yes...the man had pushed it with the bat to make it move". (Softball)
> "yes...the ball is in motion so it has to have some force in order to move". (Softball)

Furthermore, this study shows that students possess abstract ideas which are treated as if they had material existence (Osborne 1980a). For example, the belief that force is somehow imbedded in a moving object was evident in this study. For instance,

> "yes... the force applied to the ball is still moving it in the direction of the arrow...". (Softball)
> "yes... the ball is in motion so it has to have some force in order to move". (Softball)

In addition to the foregoing quotes and discussion, there was evidence of students' beliefs that were specific to the concept of force alone. One notable aspect of this was that some students believed that a non-observable force on the man on the moon was due to the presence of air. For example,

> "no ... there is no air on the moon so there is no force acting on the moon". (Moon)
> "no ... the only force that is strong is the force going upwards due to atmosphere on the moon". (Moon)

Some 50% of those students had a belief which was more consistent with scientific ideas of a force, simply a push or a pull. For example,

> "yes something that pulls the ball to the ground. Something like the force that pulls the ball towards the ground...". (Softball)

Students in this study have been taught general science in PHS. This might have resulted in some of these beliefs. Such students' beliefs may not be accurate in a physics sense. For instance, scientific terms were used incorrectly.

> "yes... the ball has potential force ... it had kinetic force from the ball is converted to kinetic force". (Softball)
> "yes... the energy applied onto the ball is still on the move..." (Softball)
> "yes, the ball is travelling through against air pressure ...". (Softball)

The concept of force of gravity was evidently something which caused great difficulty to many students. Some students appeared to accept the nature of a force because they have been told or experienced a situation, but others appeared not to accept it, probably because of the non-contact nature of this force. The difficulty in learning about force may lead to self-contradictory beliefs. For example,

> "no, on the moon there is no force there. The only force that is strong is the force going upwards due to atmosphere". (Moon)
> "no, no gravity on the moon so the force is not strong coming down". (Moon)

The belief of no gravity and no air on the moon held by students elsewhere (Osborne, 1980a) was also found in this study. For example,

> "no, there is no air on the moon so there is no force acting on the moon". (Moon)

The belief of no gravity on the moon might have been an indication of students' observation of experience of some kind of physical situations. For example, about 32% of students believed that:

> "there is no gravitational force, he is supposed to be floating but he is using some sort of machine to keep him on the moon". (Moon)

SUMMARY

Twenty-two NHS students were interviewed about four situations previously used elsewhere (Osborne, 1980a, Osborne and Gilbert, 1979, 1980) and the results of students' beliefs have been presented and discussed above.

CONCLUSION

The main assumption underlying this report is that students in the age ranging from 16 to 17 years brought with them to the NHS science classrooms various scientific beliefs about the topic of force. These beliefs might be seen as the understanding and interpretation of the natural world which students possessed before their study of science. The results indicate that the scientific beliefs held by this age group of students are very similar and to some extent common to those held by students elsewhere (Osborne, 1980 a, b; Osborne and Gilbert, 1979, 1980). These results could perhaps support previous assertions such as:

> "(1) People, young and old, have descriptive and explanatory systems for scientific phenomena that develop before they experience formal study of science;
>
> (2) These naive descriptive and explanatory systems differ in significant ways from those students are expected to learn in their study of science;
>
> (3) The naive descriptive and explanatory systems show remarkable consistencye across diverse populations, irrespective of age, ability or nationality;" — (Champagne, Gunstone and Klopfer, 1983, p. 174).

Results similar to above have also been reported from various perspectives by Champagne, Klopfer and Gunstone (1982); Driver and Erickson (1983), Osborne and Wittrock (1983).

In the development of science curricula the existence of students' beliefs has usually either been ignored or inadequately considered (Fensham, 1980).

However, the important implication of the students' beliefs is the extent to which these beliefs are retained when the explanatory systems of physics are taught. Often it is difficult to see how a student can fully understand a topic area if their beliefs remain at odds with the tenets of science. Would there be any way in which science teaching can help students to abandon these beliefs and accept those of science? Perhaps designing Pedagogical strategies that can cater seriously with the students' prior knowledge.

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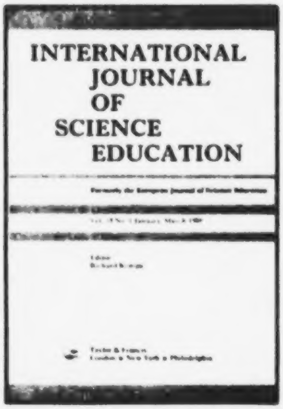

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